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MONTHLY WEATHER REVIEW

VOLUME 47, No. 2

FEBRUARY, 1919

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological and seismological contributions and bibliography; (2) an interpretative summary and charts of the weather of the month in the United States and adjacent oceans; and (3) climatological and seismological tables dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) results of observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; and (*b*) abstracts or reviews of important meteorological papers and books. In each issue of the REVIEW such contributions and abstracts are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather, applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library, U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Havana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

Supplements containing kite observations, and others containing monographs are published from time to time.

SOME WEATHER BUREAU PUBLICATIONS.

A few of the more recent Weather Bureau publications are listed below, with their prices. A complete list may be obtained upon application to the *Chief, U. S. Weather Bureau.*

To secure such publications as have a price affixed, one should apply to and make remittances payable to the *Superintendent of Documents, Government Printing Office, Washington, D. C.* Stamps and personal checks are not accepted in payment. Additional charge for postage for foreign addresses.

National Weather and Crop Bulletin, with charts, monthly from October to March, weekly during remainder of the year	25c. year.
Snow and Ice Bulletin, with charts, weekly during the winter	25c. season.
Climatological data, monthly for 42 separate sections, each section 5c. a copy	50c. a year.
Complete monthly number, 42 sections	35c. each, $4.00 year.
Monthly Weather Review Supplement No. 9. (Periodical events and natural law as guides to agricultural research and practice.)	25c.
Monthly Weather Review Supplements Nos. 10 and 11. (Aerology Nos. 5 and 6), 1917 kite data	25c. each.
Monthly Weather Review Supplements Nos. 12 and 13. (Aerology Nos. 7 and 8), 1918 kite data, etc.	25c. each.
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The daily weather map, with explanation (text and 4 charts)	5c.
Instructions for cooperative observers, 5th ed. Circulars B and C combined	10c.
Instructions for the installation and operation of Class A evaporation stations. Circular L	10c.
Report of the Chief of the Weather Bureau, 1917–1918 (4° edition)	Free.
Modern methods of protection against lightning. (Farmers' Bull. No. 842)	Free.
Notes on the climate of France and Belgium	Free.
The Weather Bureau. (Descriptive pamphlet)	Free.
Explanation of the weather map (leaflet)	Free.
Serial numbers of Weather Bureau publications	Free.
Papers on meteorology as a subject for study. (Repr. from Dec., 1918, Mo. Wea. Rev.)	10c.

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MONTHLY WEATHER REVIEW

HERBERT H. KIMBALL, Acting Editor.
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TRANS-ATLANTIC FLIGHT FROM THE METEOROLOGIST'S POINT OF VIEW.

By WILLIS RAY GREGG, Meteorologist.

[Paper presented before the Philosophical Society of Washington, March 29, 1919.]

INTRODUCTION.

The marvelous development of aviation finds no better illustration than the fact that, within 15 years of the time when flying in heavier-than-air machines was proved to be practicable, trans-Atlantic flight has become one of the leading topics in the daily press and is receiving the earnest attention of many of our most ambitious aviators. During the past few months plans for the realization of this ambition have more and more assumed a definite, concrete form, and there is every reason to believe that, within a short time, trans-Atlantic flight will have become an accomplished fact. Much has been written on this subject in the various aviation and other periodicals, but these discussions have for the most part dealt with the mechanical problems involved, including engine performance, endurance, fuel capacity, etc. Comparatively little has been written relative to the meteorological aspects of the project, although there are some exceptions, specific reference to which will be made later. It is true that improvements in aircraft may eventually result in making them less dependent upon weather conditions than at present, but it is not likely that the time will ever come when a knowledge of atmospheric conditions and changes can not be used to advantage by the aviator. Certainly at the present time, with the limited cruising radius of even the highest powered machines, weather conditions along a course as great as any of those that may be selected for crossing the Atlantic should be known as accurately as possible, in order that the aviator may know beforehand his "margin of safety" and may make his plans accordingly. The purpose of this paper is, therefore, briefly to present (1) a statement giving the present state of our knowledge relative to average surface meteorological conditions over the North Atlantic; (2) a similar statement as to free-air conditions; and (3) an analysis showing the assistance that may be rendered by the winds, providing an aviator, with this in mind, carefully selects his time for flight.

Before taking up these points in detail a few words should be said as to possible routes. Those most frequently proposed for the trip from America to Europe and return are (*a*) Newfoundland to Ireland and (*b*) Newfoundland to the Azores, thence to Portugal. Another suggested route is from Labrador to Scotland, via Greenland and Iceland. The only advantage of this route over the others is the shorter distance between successive landing points. Among its disadvantages are: Lower temperatures than over the routes farther south; difficulty of providing suitable landing places in Greenland and Iceland and of finding them even if they could be established; greater probability of cloudiness and of opposing winds, since this route lies to the north of the region of greatest storm frequency; difficulty, if not impossibility, of securing meteorological data at the time of flight; and remoteness from steamship routes and, therefore, improbability of rescue in case of accident (cf. **30**). Inasmuch as airplanes of sufficient power and capacity have been developed for flying a distance at least as great as that from Newfoundland to the Azores the extreme northern route will be given no further consideration.

For the return trip from Europe to America there have been proposed, in addition to the two already mentioned, a route from Portugal to northern Brazil, Guiana, or Venezuela (**1**); and one from Portugal to the Lesser Antilles (**2**). In these instances, however, the flights contemplated were to be made by means of relatively slow-traveling airships or dirigible balloons. For the eastward journey they were to go direct from Newfoundland to Ireland, thus adding to the inherent speed of the airship the assistance furnished by the prevailing westerlies. In returning, however, the wind resistance offered would be so great as to make the journey hazardous and on a large percentage of days impossible. The southern routes would not only avoid these head winds, but would lie for the most part in the region of the northeast trades. In spite of their greater distances, therefore, these southern routes offered decided advantages for airships or dirigible balloons. In the case of high-speed airplanes, on the other hand, the assistance furnished by the trade winds would be offset in large part, if not altogether, by the greater distance to be traveled. On properly selected days the less favorable winds along the routes farther north would be more than compensated for by the shorter distances. The several routes together with approximate distances are shown in figure 1, but in the present paper attention will be given only to those between Newfoundland and Ireland and between Newfoundland and Portugal via the Azores.

1. AVERAGE SURFACE WEATHER CONDITIONS OVER THE NORTH ATLANTIC.

References (**3**) (**4**) (**5**) (**6**).

Temperatures.—Temperatures are of interest chiefly in connection with their effect upon the aviators and upon engine performance. In Table 1 are given average monthly and annual values at four selected places.

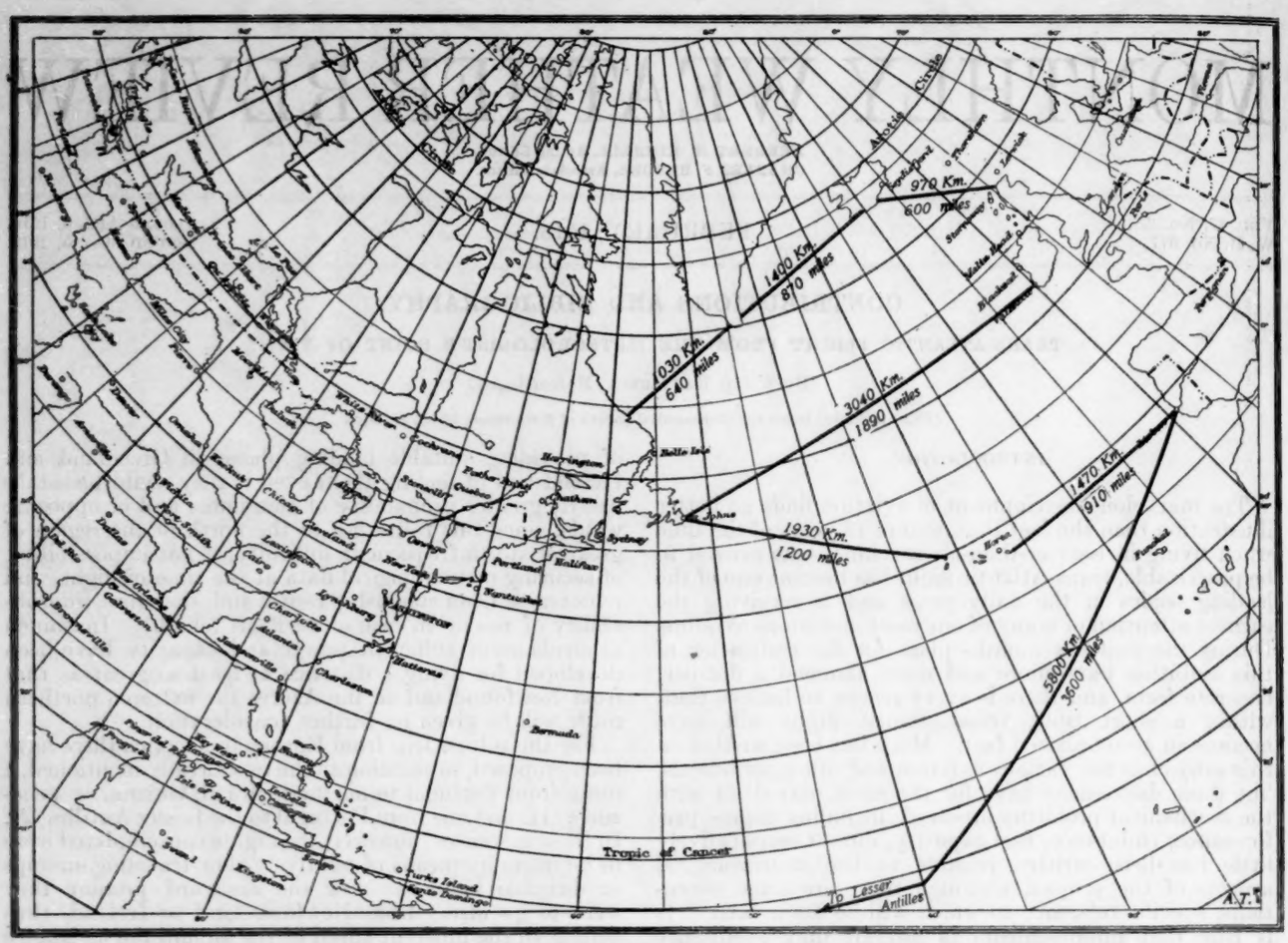

FIG. 1.—Different routes that have been proposed for trans-Atlantic flight. (Distances in kilometers and statute miles along great circles.)

TABLE 1.—*Mean monthly and annual temperatures, °C., at St. Johns, Newfoundland; Valentia, Ireland; the Azores; and Lisbon, Portugal.*

	St. Johns.	Valentia.	Azores.	Lisbon.
January	− 5	7	14	10
February	− 5	7	14	11
March	− 2	7	14	12
April	2	9	16	14
May	6	11	17	16
June	11	14	19	19
July	15	15	21	21
August	16	15	22	21
September	12	14	21	20
October	7	11	19	16
November	3	9	17	13
December	− 2	7	15	10
Annual	5	10	18	15

Annual and diurnal ranges, as well as those due to abrupt changes in weather, are greatest in Newfoundland and least in the Azores. Minimum temperatures as low as −25° C. have been observed at St. Johns and as low as −5° C. at Valentia. Freezing temperatures have never been reported in the Azores or at Lisbon. Extreme maxima do not differ greatly at the four places, Lisbon showing the highest, 35° C., and Valentia the lowest, 27° C. Over the ocean the horizontal temperature gradient is fairly steep in winter from Newfoundland to longitude 40° W. along both routes, and practically zero from that longitude to Ireland and Portugal. During the summer there is a slight rise from Newfoundland to longitude 45° W. over the Azores route; along the remainder of this course and along the entire course from Newfoundland to Ireland there is practically no change.

Relative humidity.—Comparatively little has been done in a critical way in the study of humidity conditions over the oceans. Among the most interesting observations are those on the British steamship *Scotia* (**7**) and on the U. S. Coast Guard cutter *Seneca* (**8**). These observations were made in the late spring and early summer months and showed in practically all cases a relative humidity above 80 per cent. A large number of observations in December, as computed by the marine section of the Weather Bureau, gave an average value of 86 per cent. There seems to be little, if any, variation with the seasons, but there is a small variation with latitude, values at latitude 60° N. averaging about 90 per cent, as against 85 per cent at latitudes 40° to 50° N.

Cloudiness.—The average cloudiness along the northern route is about 70 per cent throughout the year. This statement is somewhat misleading, so far as aviation is concerned, inasmuch as fogs are included with clouds in arriving at this result and, as will be shown later, these fogs extend to low altitudes only and the aviator would, therefore, oftentimes have a clear sky above him, whereas at the earth's surface 100 per cent cloudiness would be recorded. It is probable that in summer the average cloudiness above the fog level is

about 50 to 60 per cent. Between Newfoundland and the Azores it varies from 65 per cent in winter to 55 per cent in summer, and between the Azores and Portugal, from 55 to 45 per cent.

Precipitation.—Very little is known as to the amount of precipitation over the North Atlantic Ocean. Data are available, however, for the adjoining coasts and these indicate an annual amount of about 140 cm. in Newfoundland; 100 on the west coast of Ireland and in the Azores; and about 70 in southern Portugal. According to Supan (4) the average is about 200 cm. over the greater portion of the Newfoundland-Ireland route, and over part of the region between Newfoundland and the Azores; from the latter to Portugal the mean value is probably about 100 cm. Precipitation normally occurs on about 160 days in Newfoundland; 200 in Ireland; 170 at the Azores; and 100 in Portugal. Over the ocean it probably occurs on about 200 to 250 days along the northern route and on about 150 to 200 days along the southern route. In all regions precipitation is greatest in amount and frequency in winter and least in summer.

Fog.—One of the most serious obstacles to trans-Atlantic flight appears to be the large percentage of days on which fog occurs, particularly near the American coast. This amounts in the regions southeast and east of Newfoundland to about 60 per cent in summer and about 20 to 35 per cent in winter, the frequency in the latter season being greatest to the southeast. Near the Irish coast it varies from about 10 per cent in summer to 5 per cent in winter. Fogs rarely occur near the Azores or between them and Portugal. In general the Newfoundland fogs occur as the result of warm moisture-laden winds blowing from the Gulf Stream regions over the colder waters of the Labrador Current. Another and, according to Capt. Campbell Hepworth, the commonest kind of fog encountered in this part of the Atlantic is a calm-weather fog of small vertical extent in which the sea is slightly warmer than the air. In discussing this phenomenon Taylor (7) concludes "either that when a fog blows over warmer water there is no appreciable tendency to dissipate it or that, under certain circumstances, warm water under cold air tends to produce a fog in some other way than that with which we are familiar and that this effect balances the tendency of warm water to dissipate a fog produced by cooling." Probably such fogs are of a temporary nature, having already been formed under the usual conditions, but later blown over water with a higher temperature than their own. They occur only during calm weather and quickly disperse as soon as a breeze sets in.

Pressure.—Pressure distribution over the North Atlantic may be briefly described as consisting essentially of a belt of high pressure, known as the "Horse Latitudes" at about latitudes 30° to 35° N., with a semipermanent HIGH near the Azores; and a belt of low pressure at about latitude 60° N. with lowest values in the vicinity of Iceland. Because of the relative warmth of the ocean and the adjacent continental areas during the different seasons, the Azores HIGH is best developed in summer and the Iceland LOW in winter. The seasonal difference is greatest in the case of the Iceland LOW, the final result being that the northward pressure gradient is strong in winter, but relatively weak in summer. The isobars, in general, run more or less parallel to the lines of latitude from Newfoundland to about longitude 20° W. at all seasons. Farther east along the Ireland route they continue eastward in summer, but turn to east-northeast and northeast in winter, under the influence of the Iceland LOW. From the Azores to Portugal they turn southward in summer around the Azores HIGH, but are nearly west to east during the winter.

Wind.—As a result of the pressure distribution, thus briefly outlined, winds in summer are from a west-southwesterly direction, with a mean velocity of 8 m. p. s., at all points along the northern route; in winter they are westerly, with a slight north component, i. e., a component *from* the north, mean velocity about 10 m. p. s., from Newfoundland to longitude 45° W. Farther east they have a strong south component, becoming southwesterly near the British Isles. The mean velocity along this section of the course is 10 to 15 m. p. s., being highest between longitudes 45° and 20° W. Over the southern course winds in summer are southwesterly, 8 m. p. s., to longitude 40° W.; variable and light thence to the Azores; and northerly, 8 m. p. s., between the Azores and Portugal. In winter they are west-northwesterly, 10 m. p. s., to longitude 40° W.; westerly, 10 to 12 m. p. s., thence to the Azores; and west-southwesterly, 10 m. p. s., between the Azores and Portugal. The percentage of winds from a westerly direction, i. e., between north-northwest and south-southwest, varies along the northern route from about 85 in winter to 70 in summer; near the Azores, from 75 to 65; and from the Azores to Portugal, 40 to 30. In the last-named region winds from all directions are about equally frequent in winter, but in summer northerly winds predominate.

Gales.—Practically all of the cyclonic disturbances that move across the United States, no matter what their place of origin, enter the North Atlantic Ocean slightly to the south of Newfoundland, moving thence east-northeastward toward the Iceland LOW, and thus crossing the northern route roughly between longitudes 30° and 40° W. These storms vary considerably in size, intensity, and rate of travel. In general, they are larger and travel more slowly over the ocean than over the continents. They are, moreover, more frequent, more intense and faster moving in winter than in summer. In their movements across the Atlantic, the more intense cyclones are often accompanied by gales having a velocity of more than 20 m. p. s., the directions of these gales depending upon the part of the storm in which the observations are made. Thus, considering a typical case, viz, a well-developed LOW leaving New England and passing south and eventually east of Newfoundland, we should expect to have at the latter place gales successively from the east, northeast, north, northwest, and west. Along the Ireland route the percentage of days on which such gales occur varies in general from about 25 in winter to 5 in summer. In winter they are often accompanied by violent snow squalls. From Newfoundland to the Azores the percentage frequency of gales is about 20 in winter and 3 in summer; from the Azores to Portugal, about 7 and 1, respectively.

Tropical cyclones.—Tropical cyclones, or hurricanes, occur only in the summer and autumn months, reaching their greatest frequency in August, September, and October. The average number in each year is only about 3 to 5. These storms generally originate in the region between the West Indies and the northern coast of South America, whence they travel slowly northwestward, then northward, to the southeastern coast of the United States. From this region they usually move northeastward along the coast and assume the characteristics of extratropical cyclones. So far as trans-Atlantic flight along the two courses under consideration is concerned, the aviator need therefore feel no more anxiety from hurricanes than from the areas of low pressure that originate in different portions of this country and enter the Atlantic Ocean from the St. Lawrence Valley.

2. AVERAGE FREE-AIR CONDITIONS OVER THE NORTH ATLANTIC.

References (2) (9) (10) (11) (12) (13) (14) (15) (16) (17).

On this subject there is but little information available, so far as actual observations are concerned. The following discussion is, therefore, based for the most part on numerous free-air observations that have been made over the eastern portions of the United States and Canada and in different parts of Europe, and an effort is made to apply these results to the air over the ocean, bearing in mind the relative effects of land and water surfaces on the distribution of the meteorological elements above them.

Temperature.—Individual observations over land surfaces show, in the lower layers of the atmosphere, large variations in temperature gradients, from a strongly inverted condition to nearly (sometimes slightly exceeding) the adiabatic rate. The diurnal phase, so characteristic of surface temperatures, disappears at a low altitude, and at higher levels in clear weather there is usually a reversal, due probably to the greater absorption of terrestrial radiation in those levels at night than during the day. The annual variation is also less in the free air than at the surface, with the result that in winter there is on the average little change in temperature from the surface to a height of about 1 kilometer above it, whereas in summer a decrease of about 6° C. occurs. In general, it may be said that the lower the surface temperatures, as compared with the seasonal normal, the smaller is the rate of decrease with altitude. In other words, during cold waves with clear skies and especially during the early morning hours, inversions almost invariably occur. During cloudy weather, i. e., low clouds, temperatures generally decrease from the surface to the cloud layer and increase slightly for a short distance above it.

In the application of the foregoing statements to the free air above the ocean it is important to recognize certain fundamental differences between land and water surfaces in their absorption and radiation of heat. Water surfaces reflect about 40 per cent of the insolation that reaches them and absorb the remaining 60 per cent. Much of the heat thus absorbed is, however, used in evaporating the water and some of the remainder is distributed both vertically and horizontally by the constant movement of the water and by the penetration of the light rays to lower levels, the result being that the surface and therefore the air in contact with it maintains a relatively constant temperature. Land areas, on the other hand, reflect and transmit very little insolation and there is but little evaporation. The specific heat of land is low and moreover there is no movement, as in the case of water, whereby the heat received can be convectionally distributed either horizontally or vertically. Hence, land areas become strongly heated during insolation and similarly cooled in its absence.

The diurnal variation of temperature at the surface in any one locality at sea is seldom greater than 1° C. In general it is probable that the change is not much larger in the free air above the ocean, except that, in the case of coastal waters, winds blowing offshore would bring their characteristic diurnal variations of temperature with them. As has already been stated there is in winter considerable change in surface temperatures from Newfoundland eastward. This is due partly to the effect of the cold winds blowing off the American continent and partly to the difference in temperature of the Labrador Current and the Gulf Stream. In the free air this difference largely disappears. Observations on the *Seneca* invariably showed a sharp inversion above the cold Labrador Current and the coastal waters, whereas a temperature decrease of 0.5° to 0.6° C. per 100 meters was found above the Gulf Stream. Summarizing, then, we should expect to find at 1 kilometer above the sea approximately the conditions as set forth in Table 2. The summer months include June, July, August, and September and the winter months, December, January, February, and March. Transitions from one group to the other during spring and autumn are gradual.

TABLE 2.—*Probable temperature conditions, °C., at 1 kilometer above sea in different portions of the North Atlantic.*

	Near Newfoundland.		Near Ireland.		Between Azores and Portugal.	
	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.
Mean	10	0	10	5	15	10
Highest	25	10	20	10	25	20
Lowest	5	−10	5	−5	10	5

It must be distinctly understood that these figures are merely estimates; they are the nearest to actual conditions that we can get at the present time. Considered with reference to those in Table 1, they indicate that at an altitude of 1 kilometer temperature changes along both routes would be less than at the surface, that rarely would temperatures be much below freezing along any part of either route, and that in summer a trip would be attended by mild and comfortable temperatures throughout. The fogs off the coast of Newfoundland should cause no concern in this respect, for, as will shortly be shown, they are low-lying, and above them temperatures are higher than at the surface.

Humidity.—Over land areas relative humidity generally decreases with altitude during clear weather or when only high clouds of the cirrus type are present. As a rule, it falls to about 50 per cent at an altitude of 1 kilometer, but occasionally as low as 20 per cent. When there are low clouds, the humidity remains high to the upper limits of the cloud layer and decreases rapidly above it. When all conditions of weather are considered, the average decrease with height is not large, amounting to only about 10 per cent from the surface to 1 kilometer above it. It is greatest in winter and least in summer. At altitudes greater than 1 kilometer the relative humidity remains practically constant. Above the ocean, due to the higher humidities at the surface, this decrease is probably larger, amounting on the average to 20 or 30 per cent. The *Scotia* observations showed in some cases exceedingly low values at altitudes of less than a kilometer, even with dense fog at the surface. In general, it is probable that an aviator flying at an altitude of about 1 kilometer would experience along the northern route humidities of 50 to 60 per cent in clear weather or when only high clouds are present and about 80 to 100 per cent in weather with low-lying clouds. Along the southern route somewhat lower humidities than 50 per cent would prevail during clear weather, but with overcast skies they would be about the same as along the northern route.

Height of fog.—There is every reason to believe that in the great majority of cases fogs extend to a low altitude only, above the sea. This is clearly shown in the kite records obtained on the *Scotia* (7) and on the *Seneca* (8). The top of the fog is very definite, and above it the

relative humidity decreases rapidly. The temperature usually increases from the surface to the top of the fog and decreases above it. Out of nine kite records in fog obtained on the *Scotia* only one showed fog extending to a height greater than 300 meters, the average being about 150 meters. The one exception was due to long-continued blowing of warm air over successively colder areas, but, even in this case, the top of the fog was at a height of less than 900 meters. Ten kite flights in fog were made from the deck of the *Seneca*, and the temperature gradients indicate that in only one did the fog extend to a height greater than 250 meters. In the one exception it is impossible to give the exact height of the fog, as no humidity values were obtained; but the temperature record indicated an altitude of about 950 meters. In their studies of fog at sea during this and other cruises on the *Seneca*, Wells and Thuras (**18**) reached the same conclusion with respect to its height, this conclusion being based upon the fact that there is nearly always a higher temperature at the top of the mast than on the ship's deck and that, if this temperature increase continues to greater heights (and kite records show this to be true), a point must soon be reached at which fog is impossible. Additional testimony from local observers, in support of these conclusions, is contained in a recently printed report of the British civil aerial transport committee. This report was published in England during the latter part of 1918, and is briefly reviewed in this number of the MONTHLY WEATHER REVIEW, p. 80.

Winds.—Observations with kites and balloons in this country and in Europe have brought out the following facts with respect to average free-air wind conditions: Velocities are slightly greater at all altitudes in America than in Europe, but aside from this difference the same general tendencies are shown in both countries, viz, a rapid increase, amounting to very nearly 100 per cent, from the surface to about 500 meters above it; practically constant velocity in summer and a small increase in winter from the 500 to the 1,000 meter levels above the surface; and a steady increase in both seasons, but greater in winter than in summer, from the 1,000-meter level above the surface to greater altitudes. The mean seasonal difference is about 1 m. p. s. at the surface and 2 to 4 m. p. s. at an altitude of 1 kilometer. Moreover, all observations show that the increase in wind velocity from the surface to 500 meters above it is practically the same for all directions of wind, but that at higher levels winds from an easterly direction rapidly diminish in strength, whereas those from a westerly direction gradually increase. The easterly winds usually die out altogether before an altitude of 2,000 meters is reached and at higher levels westerly winds prevail. The shifting from one type to the other is usually, nearly always, clockwise with surface winds from east to south and as a rule counterclockwise with surface northeast to north winds. The amount of the turning is directly related to the angle of deviation of the surface wind direction from that of the prevailing westerlies.

Winds, as is well known, tend to flow at right angles to the direction in which the pressure gradient acts, i. e., parallel to the isobars. Owing, however, to friction and eddies, the direction of motion of the surface wind is nearly always inclined to the isobars. The amount of this inclination is greatest in anticyclonic and least in cyclonic systems, the average value on land surfaces being about 30°. Inasmuch as these disturbing influences largely disappear in the free air, we should expect the winds invariably to veer with altitude.[1] That there are exceptions to this is due to the unequal vertical distribution of temperature that often obtains in adjacent localities, thus producing in the free air isobaric systems decidedly different from those at the surface. Nevertheless, in general it is found that the winds at an altitude of 1 kilometer follow rather closely the direction of the surface isobars. This means that on the average they veer about 30° from those near the ground. The case is somewhat different over the ocean. Here there is less friction, less convection, and there are no topographic interferences at all comparable with those on land. Hence we should expect to find the winds even at the surface blowing more nearly parallel to the isobars, and an inspection of marine synoptic weather maps indicates that this is true, the average inclination being about 10°. This means that the veering of winds with altitude is about 20° less over ocean than over land surfaces. In a similar manner velocities are affected, with the result that they are higher on the sea than on land, that is, they more nearly approach true gradient velocities. It has already been stated that observations show above land an increase of about 100 per cent in velocity within the first 500 to 1,000 meters. Now, surface winds at sea are nearly twice as strong as those on land. Hence the increase with altitude over the sea is much less than over the land. In other words, a trans-Atlantic aviator would not need to fly as high as would a trans-continental aviator in order to derive the greatest possible assistance from the winds; and, conversely, in the case of opposing winds there would be less advantage in flying at a low altitude over the ocean than over the land. Whatever the wind direction, whether favorable or unfavorable, flying at low levels above the sea would be less dangerous than at similar levels above the land, because the air there is less turbulent or "bumpy," as it is sometimes called.

In the foregoing discussion an attempt has been made to present in brief form a general review of average conditions both at the surface and in the free air. A knowledge of these is of interest and importance to an aviator, but should be used with caution, for average conditions seldom occur and they would scarcely ever prevail at all points along a route as great as that from America to Europe. We now come, therefore, to the third part of the paper, namely:

3. THE ASSISTANCE THAT MAY BE RENDERED BY THE WINDS, PROVIDING AN AVIATOR, WITH THIS IN MIND, CAREFULLY SELECTS HIS TIME FOR FLIGHT.

In order to determine, under given conditions of wind, the direction toward which an airplane should be headed in order that it may keep to any desired course, and the resultant speed along that course, it is only necessary to resort to that elementary principle of mechanics, applicable to any body moving through a medium which itself is in motion, viz, the principle of the composition of speeds. For example, in figure 2 let OB represent a course which an aviator desires to follow, and OA or S_w the speed of the wind, this wind making an angle α with the line OB.

[1] This veering with altitude is at times visible in the way in which the smoke from steamers spreads. F. J. W. Whipple, in a note on "Wind structures at sea" (M. O. Circ. 26, July 22, 1918), says, "The difference in the bearing of the upper and lower parts of the smoke cloud [from my steamer] was about 5° [in about 50 ft. difference of elevation]. There was no opportunity to estimate the corresponding angle between the upper and lower wind."

Also, let S_a represent the air speed (i. e., speed in still air) of the airplane.

Then the angle β which the airplane should make with OB, in order that the latter shall be the resultant course, may be readily computed, since the sines of the two angles are inversely proportional to the two speeds, or

$$\sin \beta = \frac{S_w \sin \alpha}{S_a}.$$

Also, by completing the parallelogram, we find graphically the resultant speed, or $S_r = S_w \cos \alpha + S_a \cos \beta$.

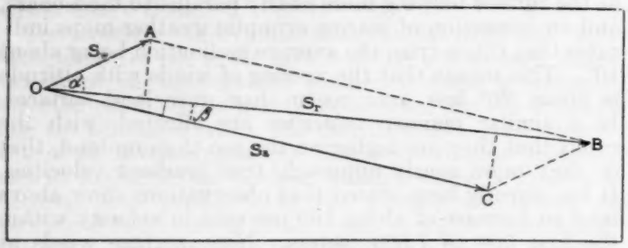

FIG. 2.—Diagram showing resultant course and speed of an airplane under the combined action of its own direction and speed and those of the wind.

To take a typical case, suppose the desired course is E. 5° S.; wind bearing and speed are E. 25° N., 10 m. p. s. (about 22 mi. p. h.); and the air speed of the machine is 40 m. p. s. (about 90 mi. p.h.). Then $\alpha = 30°$.

$$\sin \beta = \frac{10 \times \sin 30°}{40} = .1250$$

$$\beta = 7°, \text{ or } OC = \text{E. } 12° \text{ S.}$$

$$\text{Also } S_r = 10 \times \cos 30° + 40 \times \cos 7°$$
$$= 48 \text{ m. p. s., or about } 107 \text{ mi. p. h.}$$

From the foregoing brief discussion, it is evident that, with an airplane of known air-speed, the successive directions toward which the machine should be headed and the total distance covered in a given time (or the time required to fly over a given course) are quickly and easily determined, providing the prevailing wind conditions are known. The great difficulty consists in finding out, at any specified time, just what these wind conditions are. This is being done very successfully at a large number of places in this country with kites carrying self-recording instruments known as meteorographs and with small rubber "pilot" balloons, whose movements through the air are followed by means of theodolites. The data thus obtained are telegraphed to the Central Office of the Weather Bureau, and bulletins are issued for the information of aviators in the Aerial Mail Service, Army and Navy Aviation Services, etc. Another method of determining wind conditions that has been used in the war and at ordnance proving grounds, is by means of so-called "Archie" bursts, which consist of puffs of smoke from a shell, the fuse being so timed that the shell bursts at any desired altitude. The movements of these smoke puffs are observed in a graduated mirror and the wind directions and velocities at the given height are readily computed. When low clouds are present several shells are sent above the clouds at stated intervals, usually half a minute apart, an airplane of known speed flies from the first smoke cloud to the last, and the aviator is thus able quite accurately to determine the current wind conditions and to set his compass course accordingly. Still another method used in France during cloudy weather (**19**) consists in sending up small balloons which carry small charges of melinite so arranged that they burst successively at regular intervals. Sound telemeters record the explosions, and the position in space of the points of detonation can be thus determined. All of these methods are comparatively simple on land; they are less so at sea, yet some of them at least are by no means impossible, except in very stormy conditions. For example, a notable series of observations with pilot balloons was made by Teisserence de Bort and A. L. Rotch (**20**) from the deck of their steam yacht *Otaria* in 1905–1907. The ascensional rate of the balloons was known and the angular positions of the balloons were observed by means of a sextant from minute to minute. Moreover, the observations on the *Scotia* and on the *Seneca* show that kites can be used at sea with fair success. For observations by any of these methods it is advisable that the ship remain as nearly as possible in one position. Hence it would be impracticable, or at any rate difficult, to utilize trans-Atlantic steamships for this purpose. The best scheme would be to have at certain intervals along a proposed route several small ships that could make and report such observations. These ships would also be able, by means of radio communication, to act as guides for an aviator and, in case of accident, to provide a means of rescue. In order to be successful, trans-Atlantic flight, at any rate in its earlier stages, should certainly have the benefit of such assistance. Aside from the uncertainty as to wind conditions there is the added difficulty of keeping to a course, partly because of the deflective influence of the earth's rotation (**21**) and partly because of lack of precision in the compass itself. With clear skies sextant observations make possible the correct determination of position, but in cloudy weather the compass is the only guide unless the aviator can fly high enough to get above the clouds. Eventually difficulties of this sort will very likely be overcome by the perfection of radio apparatus of sufficient power to enable an aviator to keep in constant communication with points in both Europe and America. Even then, however, wind conditions along the course should be known as accurately as possible.

In case free-air observations are unavailable, there still remains the possibility of obtaining reports of surface conditions. Such reports could and should be furnished not only by specially detailed ships but also by those regularly plying between American and European ports. With these observations the meteorologist would be able to draw a synoptic weather map showing the surface conditions of pressure and wind that prevail at a given time, and from this map wind velocities at an altitude of 500 to 1,000 meters could be quickly determined usually with fair accuracy, from the well-known equation for gradient winds (**22**), viz:

$$v = \sqrt{\frac{r}{\rho}\frac{dp}{dn} + (r\omega \sin \phi)^2} \pm r\omega \sin \phi,$$

in which v = velocity in centimeters per second,

$\frac{dp}{dn}$ = difference in dynes pressure per square centimeter per centimeter horizontal distance at right angles to isobars,

r = radius of curvature of the isobar at the place of observation, in centimeters,

ρ = air density in grams per cubic centimeter,

ω = angular velocity of the earth's rotation $= \frac{2\pi}{86164}$

and ϕ = the latitude.

As previously stated, wind directions at these altitudes are usually found to be very nearly parallel to the isobars. When pressure conditions are well defined and relatively stable, comparatively small error is introduced in accepting the foregoing assumptions, but when they are very irregular or when local disturbances, like thunderstorms, squalls, etc., are occurring, the principle of gradient winds must be used with caution. In general, it is more reliable over ocean than over land surfaces, because, as already pointed out, isobaric systems are larger and move more slowly over the oceans than they do over the continents.

It is not sufficient, however, for the aviator to know the *current* wind conditions. He must also be informed as to the *changes* that are likely to occur during the latter part of his trip, and this may be as much as 20 to 25 hours in advance. Here again the meteorologist is assisted by the fact that isobaric systems over the ocean are relatively slow-moving. With this in mind and from a detailed study of the map before him he can construct a series of maps showing expected conditions at intervals of six hours, for example. From this series of maps he is able to determine the probable wind conditions that will prevail at successive points along the course at the times at which the aviator is expected to reach those points, these times being dependent, of course, on the air-speed of the machine and on the assistance furnished by the winds.

For the purpose of illustration let us consider a type of pressure distribution that is not uncommon, and endeavor to trace out the wind conditions at an altitude of 500 to 1,000 meters along a great circle course from Newfoundland to Ireland. The time selected is the 24-hour period from Greenwich mean noon, May 29, 1906, to the same hour on May 30, 1906. Figure 3 shows the pressure distribution prevailing at the beginning of this period and figure 4 shows that prevailing at the end of the period. On these maps are also indicated the great circle courses from Newfoundland to Ireland, and from Newfoundland to Portugal via the Azores. In the study an attempt has been made to trace the changes in the pressure distribution by means of intermediate maps, but these are not reproduced here. The flight is supposed to start from Newfoundland at about 2 p. m., 60th meridian time, or about six hours after the observations charted in figure 3 were made. About this much time would normally be required for the receipt and interpretation of reports.

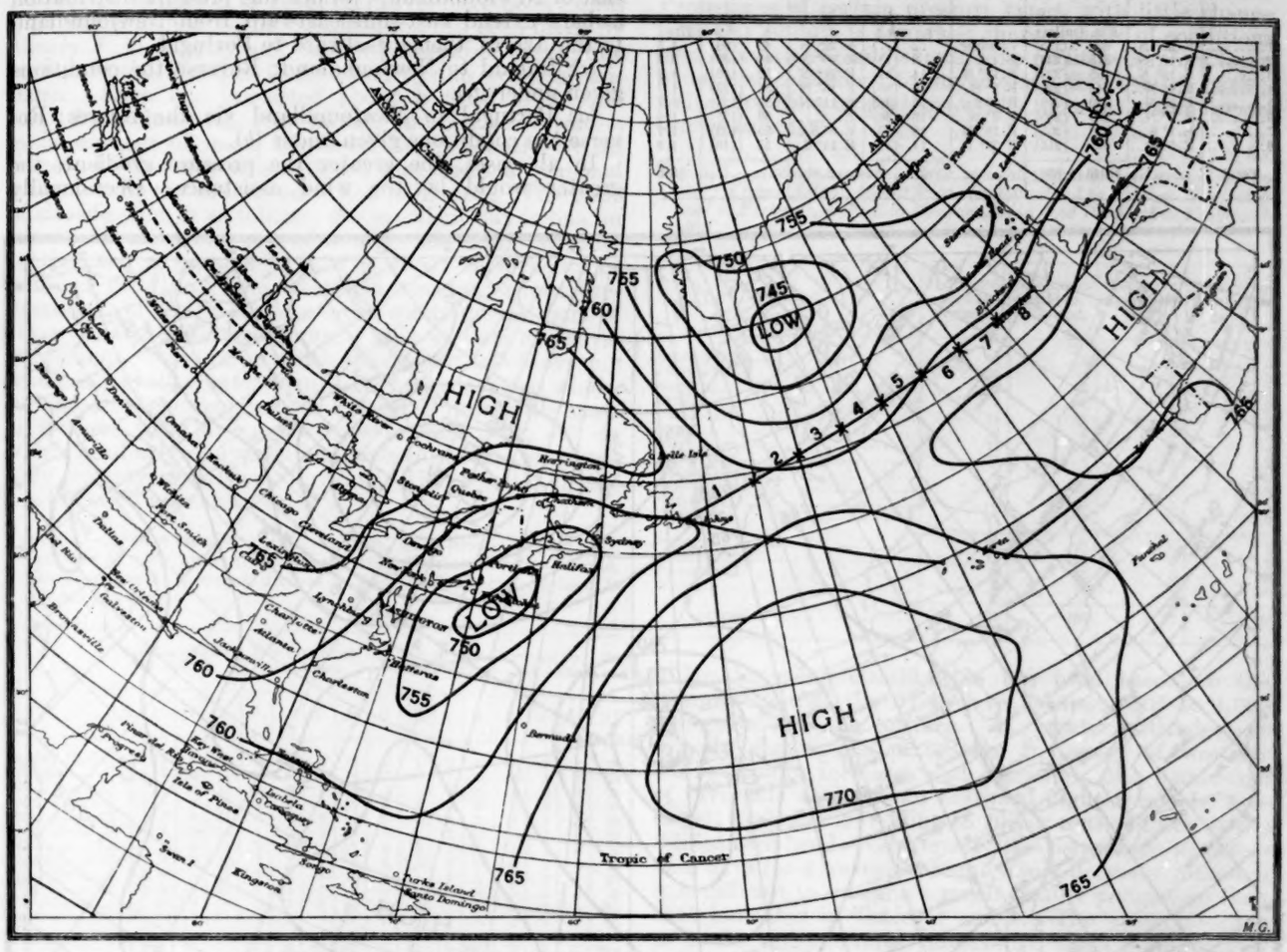

FIG. 3.—Pressure distribution, mm., over the North Atlantic at Greenwich mean noon, May 29, 1906.

Table 3 gives in some detail the results of this study. The course has been divided into eight sections as indicated by crosses in the figures and these sections are listed in column 1 of the table. Columns 2 and 3 give corresponding bearings and distances; columns 4 and 5 computed gradient wind directions and speed (22); column 6, the directions toward which the airplane

should be headed in order to keep to the courses indicated in column 2; column 7, resultant speeds; and column 8, the time required to cover the successive sections of the entire course, providing the airplane maintains a constant air-speed of 40 m. p. s.

TABLE 3.—*Time required for flight from Newfoundland to Ireland under certain specified conditions of pressure distribution and of airplane speed and control.*

Section.	Bearing.	Distances.	Gradient winds.		Airplane headed.	Resultant speed.	Time.
			Bearing.	Speed.			
		Km. (*miles*).		*m. p.* (*mi. p. s.* *h.*)		*m. p.* (*mi. p. s.* *h.*)	*Hrs.*
1	E. 22° N.	620 (385)	Variable.	.. (..)	E. 22° N.	40 (90)	4.3
2	E. 17° N.	375 (235)	E.	8 (18)	E. 20° N.	48 (107)	2.2
3	E. 13° N.	355 (220)	E. 12° S.	14 (31)	E. 21° N.	52 (116)	1.9
4	E. 9° N.	345 (215)	E. 8° S.	16 (36)	E. 16° N.	55 (123)	1.7
5	E. 5° N.	340 (210)	E. 9° S.	16 (36)	E. 11° N.	55 (123)	1.7
6	E. 2° N.	330 (205)	E. 6° N.	16 (36)	E.	56 (125)	1.6
7	E. 1° S.	330 (205)	E. 18° N.	16 (36)	E. 8° S.	55 (123)	1.7
8	E. 5° S.	345 (215)	E. 23° N.	14 (31)	E. 14° S.	52 (116)	1.8
Total		3,040 (1,890)					16.9

Briefly, this table shows that, through the assistance given by the winds, the entire trip from Newfoundland to Ireland could have been made in about 17 hours, whereas in still air about 21 hours would have been required. This period would have been fairly favorable also for the journey by way of the Azores, although less assistance would have been furnished by the winds than along the northern route. In general, "favorable" conditions for the eastward and westward trips along the two routes may be thus summarized:

(*a*) Newfoundland to Ireland: High pressure at latitudes 35° to 45° N. and low pressure at latitudes 55° to 65° N. with axes extending from west to east, so that isobars run nearly parallel to the latitude.

(*b*) Newfoundland to Portugal via the Azores: High pressure at latitudes 30° to 40° N., central near the Bermudas with crest extending eastward, and low pressure at latitude 50° N., central about 1,000 kilometers east of Newfoundland. Under this pressure distribution isobars extend east-southeastward from Newfoundland to the Azores, thence eastward to Portugal.

(*c*) Ireland to Newfoundland: Reverse the conditions given under (*a*).

(*d*) Portugal to Newfoundland via the Azores: Reverse the conditions given under (*b*).

In all cases, the greater the pressure gradient, the greater would be the wind assistance. Occasionally there is found a high-pressure area at about latitude 45° N. with its axis extending from west to east. This condition would be favorable for both the eastward flight by the northern route and the westward flight by the southern route. An unfavorable day for any of the

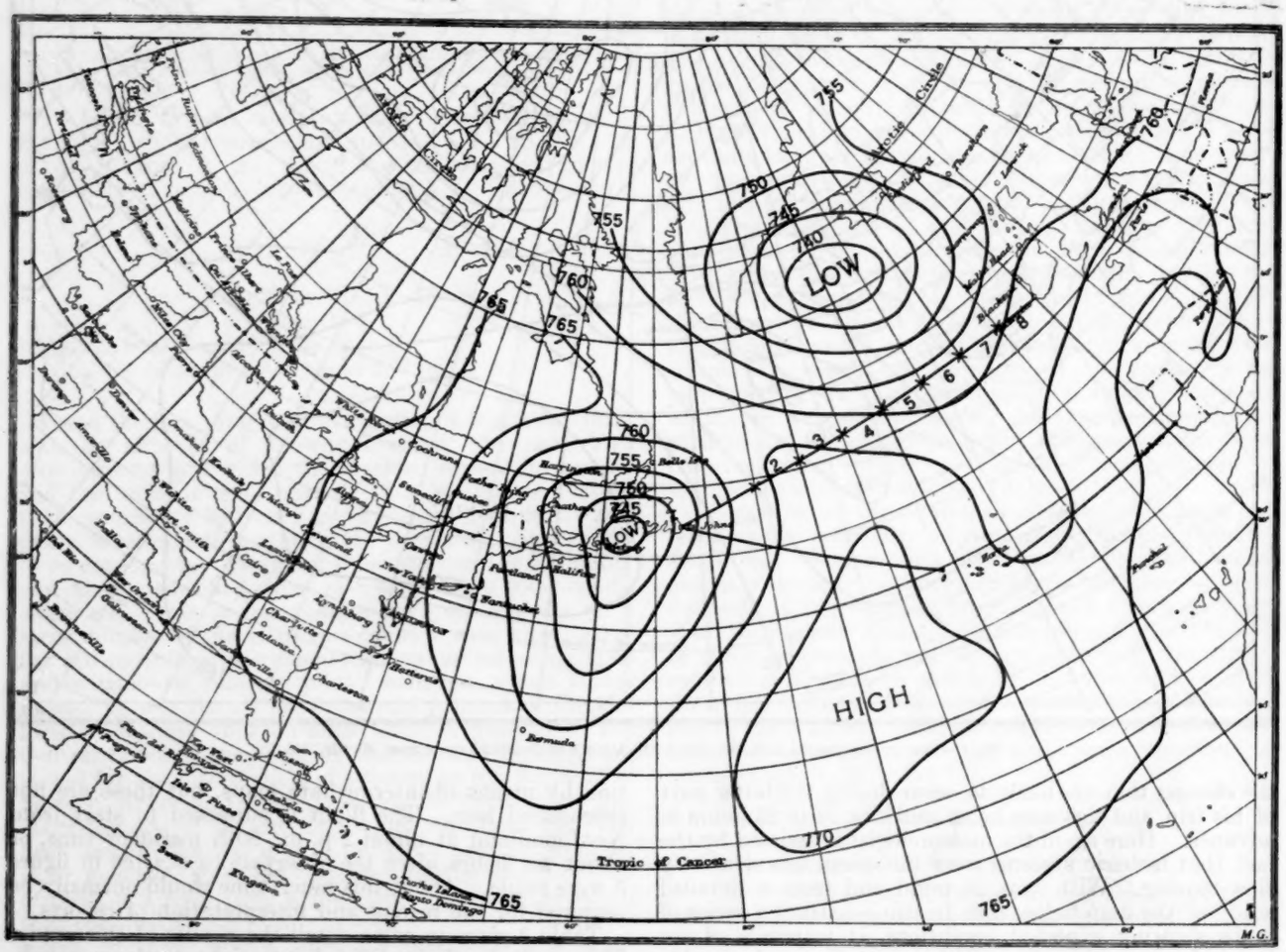

FIG. 4.—Pressure distribution, mm., over the North Atlantic at Greenwich mean noon, May 30, 1906.

journeys would be one on which conditions are the reverse of those stated under (*a*), (*b*), (*c*), and (*d*), respectively. Another type of pressure distribution unfavorable for all the journeys and one which often occurs, especially during winter, is that in which low pressure extends as a troughlike depression from north to south across both routes. Under this condition winds almost at right angles to an airplane's course would be encountered and would materially reduce the resultant speed.

In order to determine as nearly as possible, the average number of days on which favorable conditions might be expected for the four journeys during different months, all of the daily marine synoptic weather maps for the 10-year period, 1906 to 1915, inclusive, have been examined and classified. This classification has been made by Messrs. F. G. Tingley and George Paterson of the marine section of the Weather Bureau and by the writer of this paper. Each one inspected about a third of all the maps for each month, after having first compared results on a number of maps inspected independently by all three. In this way it is believed that errors of personal judgment have been reduced to a minimum. The basis of classification is as follows: An excellent day is one on which assisting winds prevail at all points along the route so that the advantage in time is about three hours or more; a good day, one on which assisting winds predominate, although head or cross winds prevail part of the way, the assistance giving a gain in time of one to three hours; fair, one on which the proportion of favoring winds is slightly greater than that of head or cross winds, so that the time required for a flight is nearly the same as if there were no winds whatever; and poor, one on which head or cross winds predominate or one on which very stormy conditions prevail. The results of the classification appear in Table 4.

TABLE 4.—*Average number of days, excellent (E.), good (G.), fair (F.), and poor (P.) for trans-Atlantic flight from Newfoundland to Ireland, Newfoundland to Portugal, Ireland to Newfoundland, and Portugal to Newfoundland.*

	Newfoundland to Ireland.				Newfoundland to Portugal.				Ireland to Newfoundland.				Portugal to Newfoundland.			
	E.	G.	F.	P.	E.	G.	F.	P.	E.	G.	F.	P.	E.	G.	F.	P.
January	8	7	4	12	5	4	8	14	0	1	2	28	3	3	4	21
February	3	7	4	14	2	7	4	15	0	0	0	28	1	1	2	24
March	3	7	4	17	3	6	6	16	1	1	1	28	0	3	3	25
April	2	5	8	15	1	6	7	16	0	2	3	25	0	2	6	22
May	5	7	4	15	3	8	8	12	0	2	2	27	1	1	3	26
June	2	8	6	14	1	5	5	19	0	2	2	26	0	2	5	23
July	6	7	8	10	2	6	11	12	1	2	5	23	1	3	8	19
August	5	8	7	11	3	5	7	16	0	1	1	29	0	2	4	25
September	3	6	6	15	3	5	8	14	1	1	1	27	1	2	4	23
October	3	8	5	15	1	8	7	15	0	0	0	31	0	3	3	25
November	1	5	6	18	0	6	5	19	0	1	1	28	0	4	3	23
December	2	9	5	15	2	9	6	14	0	1	0	30	0	2	1	28
Annual	43	84	67	171	26	75	82	182	3	14	18	330	7	28	46	284

Dropping from further consideration the two classes designated fair and poor and combining the first two classes into one group as constituting all of the days that are favorable for trans-Atlantic flight, we obtain the results indicated in Table 5.

From these two tables it is at once apparent, as was to be expected, that but little assistance from winds can be gained for the westward trip along either the northern or the southern course. For the eastward trip, however, such assistance may be expected approximately one-third of the time, the percentage of favorable days being slightly greater along the northern route, due to its lying entirely within the region of the prevailing westerlies. A detailed study of the data upon which these tables are based shows that favorable days occur on the average along the northern route 35 per cent of the time, with extremes in different years of 25 and 47 per cent; along the southern route the average is 28 per cent, and the extremes 20 and 39 per cent. When considering the monthly values we find very large variations in the same months for different years. For example, in July, 1906, there were 28 favorable days for the trip from Newfoundland to Ireland, whereas in July, 1907, there were only 4. This and several other similar cases give emphasis to the statement previously made that pressure systems over the oceans are slower moving than over the continents. Persistence of certain pressure types, with little change from day to day, is a marked characteristic of conditions over the Atlantic and should give no little comfort to an aviator who is about to undertake a flight, after having waited for days or perhaps weeks for a favorable opportunity to start.

TABLE 5.—*Average number of days, monthly, seasonal and annual, favorable for trans-Atlantic flight from Newfoundland to Ireland, Newfoundland to Portugal, Ireland to Newfoundland, and Portugal to Newfoundland.*

	Newfoundland to Ireland.	Newfoundland to Portugal.	Ireland to Newfoundland.	Portugal to Newfoundland.
January	15	9	1	6
February	10	9	0	2
March	10	9	2	3
April	7	7	2	2
May	12	11	2	2
June	10	6	2	2
July	13	8	3	4
August	13	8	1	2
September	9	8	2	3
October	11	9	0	3
November	6	6	1	4
December	11	11	1	2
Spring	29	27	6	7
Summer	35	22	6	8
Autumn	27	23	3	10
Winter	36	29	2	10
Annual	127	101	17	35

The foregoing classification has been based on the assumption that the flying level is about 500 to 1,000 meters above the surface. At greater altitudes, as already shown, the percentage frequency of westerly winds rapidly increases and, therefore, the percentage of favorable days for an eastward flight would become larger, probably increasing to 70 per cent or more at the 3-kilometer level. Conversely, the percentage of favorable days for a westward flight would decrease, although it is difficult to imagine a much smaller percentage than that indicated in Tables 4 and 5. The whole question as to the altitude most suitable for flight is still largely in the experimental stage, and the solution depends upon a thorough analysis of the various factors that enter in. For example, it is frequently found that the greatest wind assistance would be realized at an altitude of 5 or even 8 to 10 kilometers, but, on the other hand, the greater tenuity of the atmosphere at those levels would reduce the efficiency of the engine and the lower temperature and lack of oxygen would add to the discomfort of the aviator, thus making such altitudes prohibitive. Probably at the present time the most favorable height, all things considered, for trans-Atlantic flying is between 1 and 3 kilometers above the surface for the eastward trip and about 500 to 1,000 meters for the westward trip.

It is recognized, of course, that there are other meteorological factors, besides wind conditions, that enter into

the determination of the relative favorableness or unfavorableness of a day for flight, such, for example, as cloudiness, precipitation, etc. Except in so far as landing is concerned, however, wind is the one element of paramount (and, at the present time, at least, most vital) importance. Cloudiness and precipitation do not extend to very great heights over the ocean, because the high relative humidity causes condensation at a lower level here than over the land. As a rule, therefore, an aviator would be able to fly above these conditions, particularly if they covered relatively small areas. On some days stormy conditions prevail over a considerable portion of the ocean, and such days, as already stated in the paragraph preceding Table 4, have been classed as unfavorable. In this connection it is interesting, and at first thought somewhat surprising, to find that the winter season shows up so well for eastward flight as compared with the other seasons, but it should be remembered that whenever conditions *are* favorable during that season, they are decidedly so, because of the greater strength of the prevailing westerlies at that time of year. Many days in summer, otherwise excellent, have only light and variable winds and have therefore been classified as fair. The transition seasons, spring and autumn, have, on the one hand, more stormy days than does summer and, on the other hand, more quiet days than does winter. Hence, the percentage of favorable days is less than during the two extreme seasons.

In this paper attention has been confined for the most part to the application of meteorological conditions over the Atlantic Ocean to flight with heavier-than-air machines. The statements made apply equally well to airships. These, however, by reason of their greater capacity for fuel, and owing, moreover, to the fact that they are not dependent on motive power to sustain them, are capable of remaining in the air a relatively long time and are therefore not so vitally dependent upon favorable wind conditions as are airplanes.

CONCLUSIONS.

1. In the present stage of their development and until improvements give them a much larger cruising radius than they now have, airplanes can not safely be used for trans-Atlantic flight except under favorable conditions of wind and weather.

2. Observations of conditions over as great an area as possible, and particularly along and near any proposed course, should therefore be available at as frequent intervals as possible, these observations to include free-air as well as surface conditions.

3. With such observations at hand the meteorologist is able quickly to determine the current and probable future wind conditions along a proposed route and to advise an aviator as to the suitability of a day for a flight.

4. If a day is favorable, the meteorologist is able to indicate the successive directions toward which an airplane should be headed in order to keep to any desired course; also, to calculate the assistance that will be furnished by the winds.

5. Inspection of marine weather maps shows that at an altitude of 500 to 1,000 meters conditions are favorable for an eastward trip approximately one-third of the time, the percentage being slightly greater along the northern than along the southern route. At greater altitudes the percentage of favorable days materially increases, especially along the northern route. For the westward trip the percentage of favorable days is so small as to make trans-Atlantic flight in this direction impracticable until the cruising radius of aircraft is increased to such an extent that they are relatively independent of wind conditions.

6. All things considered, conditions for an eastward flight are most favorable along the northern course; for a westward flight they are most favorable along the southern course; that is, the prevailing westerlies are less persistent along this course than farther north.

7. There seems to be little choice as to season, for, although the prevailing westerlies are stronger in winter than in summer, yet on the other hand, stormy conditions are more prevalent in winter, and the net result is about an equal percentage of favorable days in the two seasons. Moreover, the greater fog percentage in summer just about offsets the greater percentage of cloudiness in winter. Fog is a disadvantage chiefly because of its interference in making observations with drift indicators. The Newfoundland fogs in general are of small vertical extent and do not extend far inland. They should not, therefore, prove a hindrance to landing, if the landing field is located some distance from the coast.

8. Most important of all, there is need for a comprehensive campaign of meteorological and aerological observations over the North Atlantic (**23**) in order that aviators may be given data for whose accuracy the meteorologist need not hesitate to vouch, instead of information based on so small a number of observations, particularly of free air conditions, that the deductions, including some of those in this paper, are assumed and not proved, are given with caution, and are "subject to change without notice."

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THE FLIGHT OF AIRCRAFT AND THE DEFLECTIVE INFLUENCE OF THE EARTH'S ROTATION.

By CHARLES F. MARVIN, Chief of Weather Bureau.

[Paper presented before the Philosophical Society of Washington, March 29, 1919.]

It is well known that objects moving freely over the earth's surface are deflected constantly to the right by a force given by the equation

$$f = 2mv\omega \sin \phi \qquad (1)$$

in which m = mass of the body, v its velocity, ω = the angular velocity of the earth's rotation, and ϕ the latitude. For each gram of matter moving at airplane speeds, say, 90 miles per hour (4,000 cm. p. s.) and at latitude 50° the force is,

$$f = 2 \times 4{,}000 \frac{2\pi}{86164} \sin \phi = .447 \text{ dynes.}$$

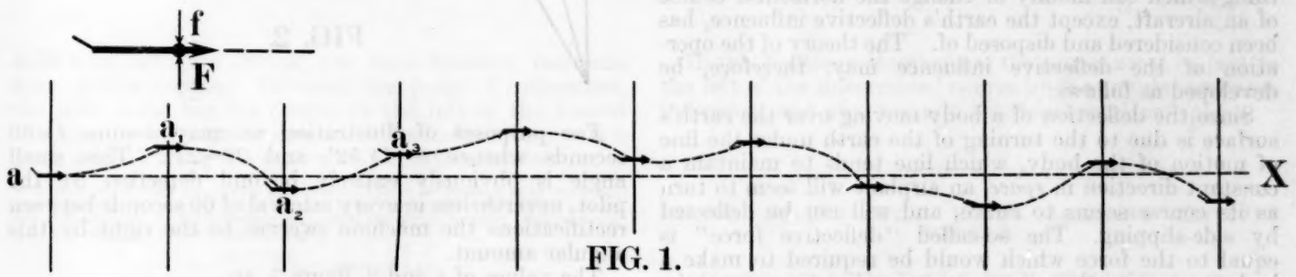

FIG. 1.

An aircraft is a body subject to such an influence even though its course be continuously controlled by a pilot and it is interesting to ascertain the quantitative effects of this small force under practical conditions of flight, as, for example, over trackless wastes where positions must be determined from the compass aided by processes of dead reckoning. For this study we can entirely disregard the influence of any winds or similar atmospheric motions, because if the conditions are known these effects can all be accounted for separately and on their own merits. Such effects on our aircraft are quite independent of the deflective influences with which alone we are now concerned. The actions we wish now to consider are such as might be observed in still air.

To ascertain how the deflective influence modifies the course of an aircraft it is necessary to make some assumptions as to how it is directed and controlled. For this purpose we assume a pilot desires to fly from a to X (fig. 1). The compass direction of X from a is supposed fully known, that is, all corrections, variations, errors, etc., are duly accounted for.

The pilot is assumed to set his craft true to course. Presently, however, close attention to the compass shows him his craft is headed a greater or less angular amount away from course. The craft is again set true to course, only presently again to be found off course. These operations of rectifying the flight of the craft are repeated many times on a long course, with the supposed result that the craft practically follows the line aX.

The short arrows in figure 1 indicate the successive positions and alignment of the *axis* of the machine just after the course has been rectified. The axis of the machine is defined to be a line through the center of mass which coincides with the instantaneous path of that center when the machine is flying normally through a stationary atmosphere over a stationary earth, or over the rotating earth near the Equator.

With the enlarged arrow in figure 1 is shown the horizontal force F which is the resultant of all the horizontal motor or air forces, resistances and reactions to which the machine is subject when in horizontal flight at a uniform velocity. The other force f represents the deflecting force due to the earth's rotation. If F and f are opposite and equal the path of the plane will be rigorously a straight line,—a great circle.

Except when he wishes to execute a relatively short turn the pilot has no control over, or knowledge of the residual force F or the direction of its action, which falls to the right or the left of the course in an entirely accidental manner. When the pilot sets his craft on a straight-away course he imagines the force F is zero, and in occasional cases this may be true. In general, however, F will have a finite value which, although relatively small, will generally be several times the value of f. The larger force will therefore dominate the flight in all cases and swerve the machine to the right or the left of the course somewhat as shown in figure 1.

In so far as the force F itself is concerned, it is believed we may properly assume that its nature is such that perturbations from course due to it are quite accidental, and in the many rectifications which must be made in any case the influences of F will tend to be automatically eliminated or averaged out. That is, ΣF for even a comparatively small number of cases continually tends to be zero. Accordingly, in a long flight

such as indicated in figure 1, if executed at or near the Equator, where f is zero or inappreciable, the machine would actually fly true to course. In higher latitudes, however, the force f is larger, and in the Northern Hemisphere acts in a manner to swerve the machine always to the right.

The assumption that $\Sigma F=0$ is nearly equivalent (so far as the effects of the force f are concerned) to the assumption that on the average, when the pilot sets his machine true to course, $F=0$; that is, there is no accidental error inherent in the setting, and accordingly the machine each time must fly true to the course set except for the deflective influence.

Possible side slipping has not been considered as yet. Except for possible faulty arrangement of wings or controls, side slipping in normal flight should be an entirely accidental feature, and as in the case of F, the sum of effects of side slipping must tend to average out.

There now remains only one final point of assumption, which, however, is probably the most important of all, namely, what is the average interval of time between necessary rectifications of the course? The value of the average angle of deviation at the time of rectification is also of some consequence, but the accidental influences tend to make this angle large and thus cause very frequent rectifications of the course which might otherwise be infrequent. For further analysis let $t=$the average interval in seconds between rectifications of the course.

Under the foregoing assumption and conditions everything which can modify or change the horizontal course of an aircraft, except the earth's deflective influence, has been considered and disposed of. The theory of the operation of the deflective influence may, therefore, be developed as follows:

Since the deflection of a body moving over the earth's surface is due to the turning of the earth under the line of motion of the body, which line tends to maintain a constant direction in *space*, an airplane will seem to turn as its course seems to curve, and will not be deflected by side-slipping. The so-called "deflective force" is equal to the force which would be required to make a body move in the same compass direction over the surface of the moving earth, just as "centrifugal force" is equal to the force required to keep a body moving on a curved path from flying off on a tangent. The path followed will then be that of a freely moving body acted upon by no other deflecting force than that of the influence of the earth's rotation.[1] Its radius of curvature is given by the equation:

$$r=\frac{v}{2\omega \sin \varphi} \tag{2}$$

For distances r measured in meters and for velocities v in meters per second, the equation becomes

$$r=\frac{(\log^{-1}3.83612)v}{\sin \varphi} \tag{3}$$

In figure 2, aX is the desired course of the aircraft and it sets out on this course at a. After the brief interval of time t, just at rectification, the craft, on the average, will occupy a position a_2 at the right of the course and it will be moving in the direction $a_2 X'$ which makes an angle 2θ with the desired course.

[1] Relative to the earth's surface, the deflection has a vertical as well as a horizontal component. An eastward moving body will weigh less than an identical westward moving body, since their absolute speeds are increased or decreased respectively. In this paper only the horizontal component of deflection will be considered.

Let the latitude be 50° and let $v=40$ meters per second, which must be reckoned as velocity over the earth and not relative to the air.

For these conditions $r=358{,}000$ meters.

The arc traversed in time $t=vt$.

The angle subtended $=360°\frac{vt}{2\pi r}=2\theta$

$$\therefore \theta=\frac{90vt}{\pi r} \text{ or } \frac{360°}{86164}\, t \sin \varphi, = (\log^{-1}3.62097)\, t \sin \varphi. \tag{4}$$

The angle θ becomes greater in proportion to the lapse of time t between the rectification of the course of the machine, and diminishes as the latitude diminishes.

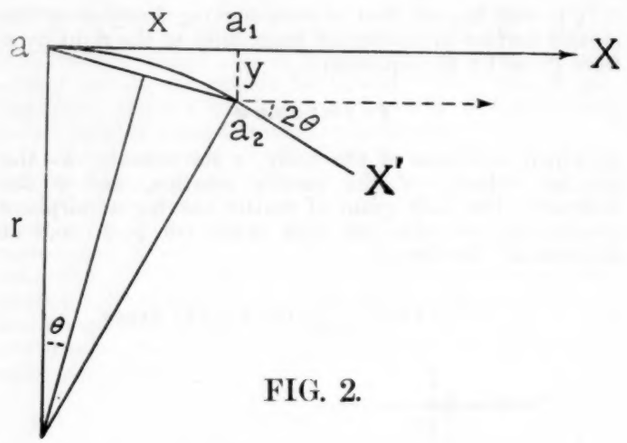

FIG. 2.

For purposes of illustration we may assume $t=60$ seconds whence $\theta=11.52'$ and $2\theta=23'$. This small angle is obviously entirely beyond detection by the pilot, nevertheless in every interval of 60 seconds between rectifications the machine swerves to the right by this angular amount.

The values of x and y, figure 2, are

$x=r \sin 2\theta = vt$ very nearly.

$y=x \tan \theta$ or $2r \sin^2 \theta = vt \sin \theta$ very nearly.

The lateral displacement from the course when the flight is rectified once each minute is, therefore,

$y=8.04$ meters per minute.

From this result it follows that a machine flying in latitude about 50° on a 10-hours' run with rectification of course no more nor less frequently than once a minute will tend systematically to miss its destination by nearly 5,000 meters to the right thereof. This is doubtless a small error in a run of this magnitude, but the displacements y from course increase rapidly should the length of time between rectifications increase.

Occasionally, as has been mentioned, the force F may be actually zero after some of the rectifications and the craft will then seem to hold its course for several minutes, that is, longer than usual, because the force f alone is too small to swerve the machine out of course quickly. From (4) we have

$$t=\frac{(\log^{-1}2.37903)\theta}{\sin \varphi} \tag{5}$$

which is the time required for the deflective force to produce an angular deviation from course of 2θ

If we assume that the pilot either does not perceive or that he disregards deflections from course smaller than, say

one-quarter point on the compass, that is, about 3°, then from (5)

$$t = 468.7 \text{ seconds} = 7.81 \text{ minutes}$$

which is the time required under conditions assumed for the deflective influence acting alone to produce an angular deflection from course of 3°.[1] The value of y in this case is

$$y = 490.7 \text{ meters.}$$

If controlled according to this condition the pilot would miss port at the end of a 10-hour flight by over 29 kilometers which would of course be a very serious matter.

It is easy to see from the foregoing that if a pilot sets out to go to a given point X from a, figure 3, and governs his flight according to the conditions assumed he will not traverse the line $a\ X$, but will tend to follow such a line as $a, a_1, a_2 \ldots\ldots a_n \ldots X'$

From the theory already stated the angle θ subtends one-half the arc traversed by the machine under the deflective influence during the time between rectifications of the course. To reach the point X, therefore, the pilot must lay his course to the left of the known direction by an angular amount $= \theta$ which in a sense is a small angle having the nature of a compass correction.

As may be seen from equation (4) this angular correction depends only on the latitude and the time interval t between rectifications of the course. It is, therefore, independent of the velocity of the craft. Moreover, the whole theory applies with equal force to marine as well as aerial navigation.

In conclusion there is given below a small table of compass corrections resulting from these studies.

Compass corrections to overcome the deflective influence of the earth's rotation on the navigation of marine and aerial craft.

(Based on a rectification of the course at intervals of 60 seconds. Corrections for other time intervals may be found by multiplying the tabular correction by the ratio of the desired interval, expressed in seconds, to 60 seconds.)

Latitude.								
° 10	° 20	° 30	° 40	° 50	° 60	° 70	° 80	° 90
Compass corrections in minutes of arc.								
′ 2.61	′ 5.14	′ 7.52	′ 9.67	′ 11.52	′ 13.03	′ 14.13	′ 14.81	′ 15.04

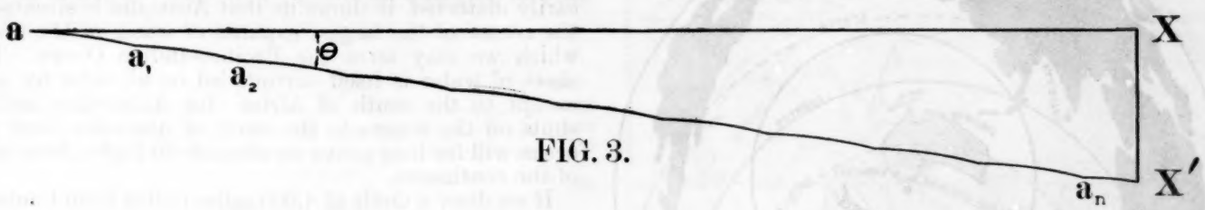

FIG. 3.

In the Northern Hemisphere the course must be laid to the left of the uncorrected course by the angular amounts indicated, and vice versa in the Southern Hemisphere.

[1] If the machine were left entirely uncontrolled, that is, not rectified as to course, still assuming $F=0$, we have the case of the craft in continuous flight at uniform velocity, but acted on solely by the deflective influence of the earth's rotation. Making $\theta = 180°$ in (5) and reducing time to hours, T, we get,

$$T = \frac{\log^{-1} 1.07800}{\sin \varphi} = 15.62 \text{ hrs. for } \varphi = 50°$$

which is the time required for any freely-moving body to execute a complete gyration, which will be nearly but not quite a closed circle.

The general equation for the motion of unit mass (1 gram) of a body moving in any of the curved paths in figure 1 is

$$\frac{v^2}{r} = F \pm f = F \pm 2v\omega \sin \varphi \qquad (a)$$

Plus for right-hand turns in the Northern Hemisphere, minus for left-hand turns.

Solving (a) for v we get

$$v = \sqrt{Fr + (r\omega \sin \varphi)^2} \pm r\omega \sin \varphi$$

From (a) we may also get, with (4)

$$\left(\frac{F}{f} \pm 1\right) = \frac{v^2}{rf} = \frac{v}{2r\omega \sin \varphi} = \frac{86164\,\theta}{360\,t \sin \varphi}$$

in which 2θ is the arc traversed in time t seconds. For $\theta = 1.°5$ and $t = 60$ seconds,

$$\left(\frac{F}{f} \pm 1\right) = \log^{-1} 0.98272, \text{ or } 7.811$$

$\therefore F = (6.811\,f)$ for right-hand motion and $(8.811\,f)$ for left-hand turns of same radius and same velocity.

These differences of force F at same velocity and radii of turn are possible only when associated with different expenditures of power. See also pp. 88–89.

UNITED STATES STILL HOLDS AIRPLANE ALTITUDE RECORD.

[Reprinted from Aviation, New York, Mar. 15, 1919, Vol. 6, No. 4, p. 234.]

America still holds the world's airplane altitude record with 28,900 feet, set September 18 last by Maj. E. W. Schroeder, A. S., at Wilbur Wright Field, Dayton, Ohio.

Since January 2 it had been believed that Capt. Lang of the Royal Air Force had topped this climb by 1,600 feet in reaching a height of 30,500 feet in England. On March 11, however, a cable message from the London Graphic to the authorities of the Aeronautical Exposition in Madison Square Garden said that a rereading of Capt. Lang's instruments had fixed his altitude at 27,000 feet, leaving a clear margin in Maj. Schroeder's favor. The American made his climb in an American-built Bristol airplane, equipped with a 300-horsepower Hispano-Suiza engine.

AIR ROUTES TO AUSTRALIA.

By DR. GRIFFITH TAYLOR,
Physiographer in the Commonwealth Weather Service.

[Dated Melbourne, Australia, Feb. 21, 1919.]

Lord Montague, the authority on aeronautics, in a recent lecture, has said:

> It is clear that meteorology and the study of wind currents is going to be of supreme importance. The knowledge of the world's atmospheric conditions and accurate forecasts, apart from their inherent scientific interest, may effect the saving or spending of millions of money annually when postal and commercial aviation is established.

The advent of steam has decreased the economic importance of surface winds and currents, but the sailing

FIG. 1.—The isolation of Australia.

ships in the Australian trade are still bound by weather laws, and have only one route. They come from Africa to Australia, and return to Europe via Cape Horn. The reverse route—though possible—involves permanent head winds and unfavorable currents which take it out of the realms of economic trade. Much more will the air routes depend on the variations of weather and climate.

The study of surface winds and of the general circulation of the atmosphere dates back to very early times, but it was first put on a firm basis in 1856 by Ferrel's and Maury's treatises. The first experimental investigations of upper currents, apart from the study of clouds, volcanic banners, etc., were made about 1890, and a little later the Hargraves box kite (invented in Australia) was used profitably in America for this purpose.

It is, however, only in the last 20 years that the exploration of the upper air has been carried out at all generally, but now research is worldwide. For instance, in 1911 Simpson first sent up sounding balloons in Antarctica (where the writer was initiated), and in 1913 and 1914 the upper air of Australia was investigated in the same way at Melbourne. The conditions over our northern regions are almost unknown, and we depend on Java for any knowledge that is available.

Like so many scientific experiments their immediate practical value was not obvious to the man in the street. Now, however, that aviation has come to its own, these explorations of the upper air have already proved of value. The American Government has devoted $100,000 to meteorological research connected with military aviation; and it is to be hoped that our military and political authorities will show more interest in the future than they have hitherto done in the matter.

Let us now see which are the most promising routes to our isolated continent. The writer has given the matter considerable attention in his lectures at the aviation school. In figure 1 is given a somewhat unusual world map (on Sylvanus' projection), where the position of Australia with regard to the other continents is well brought out. Though the edges of the map are necessarily distorted, it shows us that Australia is situated in the center of the largest expanse of water in the world, which we may term the Pacifico-Indian Ocean. This sheet of water is itself surrounded on all sides by land, except to the south of Africa—for Antarctica entirely shuts off the waters to the south of Australia—and this ocean will for long prove an obstacle to flights from most of the continents.

If we draw a circle of 4,000 miles radius from Canberra (which is happily placed almost at the center of population of Australia), we find that it passes right through Antarctica (near the South Pole), but includes none of

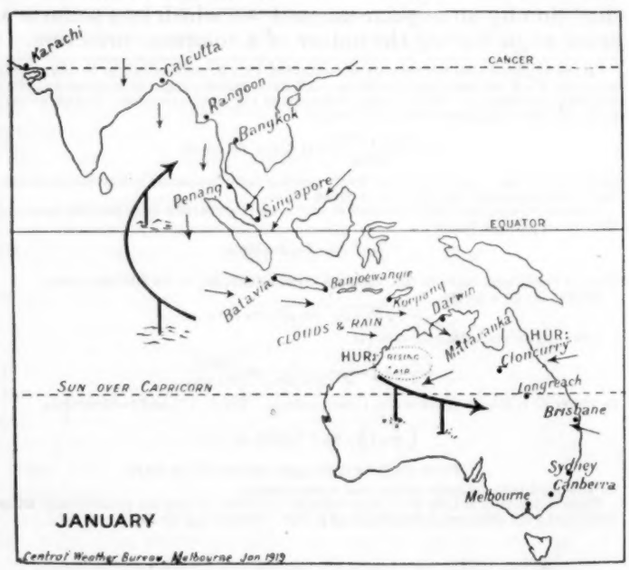

FIG. 2.—Dominant winds in January. Upper-air currents on stilts.

the other large masses. Our nearest continent is therefore of little use as a flying depot. Africa and the Americas are ruled out by distance; they are separated from us by 7,000 miles of water, with but few islands in most directions. There remains, therefore, Asia—and it is by way of India and the Straits Settlements that we may expect our earlier aeroplane services to travel.

Nature has placed stepping stones from India to Australia in the form of the drowned volcanic ranges, which are, of course, the islands of Sumatra, Java, and Timor; and these lead directly to Darwin, the chief settlement on the north coast.

We have all read of the recent flights from England to India; they were accomplished with comparative ease in about four days and will soon become almost weekly occurrences. I have drawn up a list of stations from Calcutta to Canberra with their distances. At all of these, except perhaps Koepang and Mataranka, there are, I believe, stores of petrol and facilities for repair. (See fig. 2.)

As regards the time occupied, Lord Montague in his paper on the World's Air Routes assumes about 1,200 miles per day as the average passenger-plane speed. Mr. Holt-Thomas in a recent lecture before the Aeronautical Society showed a map of the world crossed by air routes, where Sydney is only five days from England. This is twice as rapid as the recent flight and is probably much more rapid than the earlier services are likely to accomplish regularly. I have assumed 1,500 miles in 24 hours, which makes it about four days from Calcutta to Canberra, allowing for favoring winds.

FIRST DAY.

Calcutta—	Miles.
Rangoon (Burmah)	650
Bangkok (Siam)	350
Penang (Malay States)	580
	1,580

SECOND DAY.

Penang (Malay States)—	Miles.
Singapore (Malay States)	350
Batavia (northwest Java)	560
Banjowanjie (southeast Java)	520
	1,430

THIRD DAY.

Banjowanjie—	Miles.
Koepang (Timor) (here follows the only oversea journey)	680
Darwin	500
Mataranka (suggested inland capital, N. T.)	250
	1,430

FOURTH DAY.

Mataranka—	Miles.
Cloncurry	600
Longreach	300
Brisbane	600
	1,500

FIFTH DAY.

	Miles.
Brisbane to Sydney	500
Brisbane to Canberra	600
Brisbane to Melbourne	900

Let us look more particularly into the meteorological factors on this route. It lies almost entirely in the monsoon and trade-wind regions, whose climates differ materially from those to which most of us are accustomed.

The trade wind is a surface wind blowing from the southeast (over Australia) to the Equator. (See fig. 3.) Its limits vary during the year, for the belt is farther north in winter than in summer, moving with the sun. In our winter (July) these winds reach the Equator, i. e., almost to Singapore, and will obviously hinder the aeroplane coming from India, but will help the return flight. In our summer (fig. 2) their influence is not felt much north of the Tropic of Capricorn, and only the last day's journey from India will be affected. In the Northern Hemisphere the trade winds blowing from the northeast will be cross winds in January and will be obliterated in July by the periodical monsoons.

Very little research on the limits of the trade winds either in height or in latitude has been done in the Southern Hemisphere, but the following notes embody what is available.

The trade wind in North Queensland blows on an average about 20 miles per hour for weeks at a time, but it is probably less in other portions of its belt. This steady drift can obviously affect very considerably the velocity of the plane. This layer of the trade winds is, however, of limited thickness, for above it blows a poleward return wind. This is reached about 12,000 feet above sea level near the Tropics (according to German data), but is lower in temperate regions. It is often reached in ascending 4,000 feet above Melbourne, and high regions like Kosciusko experience the west wind very frequently. We know nothing directly of its depth in our Tropics.

These heights mentioned are quite those of the regular flight zones. Hence our air captain will doubtless fly from the Equator to southern Australia at high levels

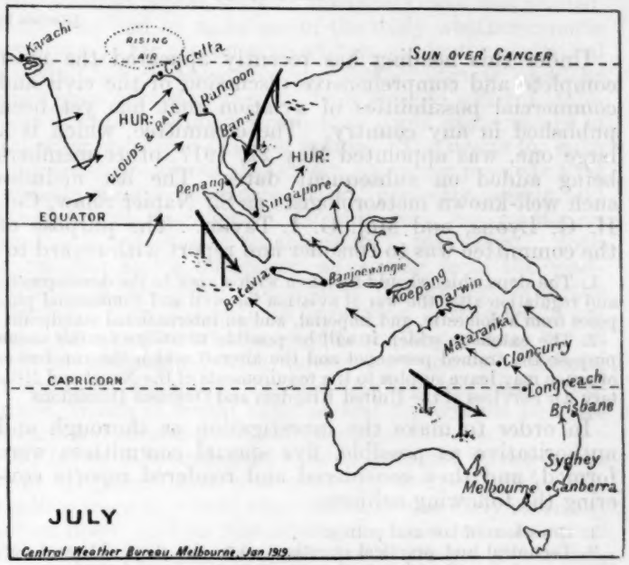

FIG. 3.—Dominant winds in July. Winds of the upper-flying layers on stilts.

when the surface winds in July are against him in this permanent antitrade wind. At these elevations wind forces are much stronger, for there is little friction due to obstructions or turbulent eddies at heights above a mile. For instance, at the upper flight limit the winds in temperate latitudes have an average of about 60 miles per hour.

During the summer seasons in the region discussed there is the maximum development of monsoons. The strong southwest monsoon of India blows during the hot months and is accompanied by dense clouds, thunderstorms, and much rain. These winds are not favorable either in direction or in their accompanying meteorology for aviation. But here again they are confined to the lower 12,000 feet, and above this (as the Dutch have shown in Java) are found trade winds. The winter monsoon is practically the same as the trade wind.

In Australia the northwest monsoon blows in our northern regions during the three hottest months. It is a turbulent wind layer, and probably the aviator will prefer to fly above it, though the dominant monsoon wind from the northwest would help him to the south.

Its extent and character can only be surmised at present.

Where the sun is vertically overhead the air is rising, and though these are calm regions at the surface they are certainly turbulent areas in the flight zone. However, though heat bumps on a large scale may be apparent, they have not much significance for a modern plane and can be avoided by high flying.

The most violent storms of the Tropics are the occasional hurricanes. Luckily these are confined to the oceans and rarely cause much damage far inland. They are prevalent in summer in the regions indicated, but aeroplanes flying overland will not often be dangerously affected. This is an unknown field of research, but one which it is disastrous to postpone much longer.

The southern portion of Australia is dominated by anticyclones at the surface, and by the westerly drift above. Here we are on more familiar ground. The anticyclones are surrounded by variable winds, generally unimportant from the present point of view. They have clear skies and afford good flying weather. The aviator will be interested in the more intense LOWS (or cyclones) which periodically travel across southern Australia, but they are regularly forecast and should not catch him unprepared for their clouds, rain, and strong winds.

I began this article with a quotation and will conclude with one. Lieut. Col. O'Gorman, in the last Wilbur Wright Memorial lecture, stated:

> Commercial aeronautics is bound up with using the [special] values which accrue incidentally to the employment of aircraft. I take three of these: (A) Speed of transit, (B) Directness of route, (C) The utilization of helpful winds and evading bad weather.

Much more might be written on this topic, but it is hoped that the reader will now realize how intimate is the connection between meteorology and aviation, and also how much remains to be done in a scientific preparation for the forthcoming aerial traffic.

REPORT OF THE BRITISH CIVIL AERIAL TRANSPORT COMMITTEE.[1]

[Review by W. R. GREGG.]

Under this heading has recently appeared the most complete and comprehensive discussion of the civil and commercial possibilities of aviation that has yet been published in any country. The committee, which is a large one, was appointed May 22, 1917, other members being added on subsequent dates. The list includes such well-known meteorologists as Sir Napier Shaw, Col. H. G. Lyons, and Maj. G. I. Taylor. The purpose of the committee was to consider and report with regard to:

1. The steps which should be taken with a view to the development and regulation after the war of aviation for civil and commercial purposes from a domestic, and imperial, and an international standpoint.
2. The extent to which it will be possible to utilize for the above purpose the trained personnel and the aircraft which the conclusion of peace may leave surplus to the requirements of the Naval and Military Air Services of the United Kingdom and Overseas Dominions.

In order to make the investigation as thorough and authoritative as possible, five special committees were formed, and they considered and rendered reports covering the following subjects:

1. Questions of law and policy.
2. Technical and practical questions as to the possibilities of performance of aircraft and as to the requirements of aerial services.
3. Business questions relating to the position of the aircraft manufacturing industry after the war, the probabilities of the establishment of aerial transport services and the steps which would be necessary for the maintenance of this industry and for the development of these services.
4. Questions of labor arising in the aircraft manufacturing industry and in aerial transport services.
5. Problems of scientific research and the special education of expert designers, engineers, and pilots.

The report of Special Committee No. 5, and the comments thereon by the Main Committee, are of special interest to meteorologists. Memoranda from Sir Napier Shaw, Col. Lyons, and Maj. Taylor set forth in some detail the character of the investigations that are being regularly conducted by the Meteorological Office and point out the need of development and enlargement along certain lines, in order to furnish aviators with reliable information as to conditions along any selected course. After considering the recommendations contained in these memoranda, the Special Committee calls attention to the following points:

> The necessity for a closer study of atmospheric conditions at great heights.
>
> The investigation of the phenomena of mist and fog and abnormal air currents in special localities.
>
> The necessity for an organized scheme for improving the supply of information from the meteorologist to the flier and vice versa.
>
> The desirability of preparing meteorological information in a form most suitable for aviators from the existing material, not only for the United Kingdom, but for so much of Europe and for such air routes as may be selected.
>
> The necessity for increased facilities for aeronautical research at the Meteorological Office.
>
> The necessity for local meteorological establishments at appropriate terminal aerodromes, connected by telephone with the Meteorological Office and with each other.
>
> The necessity for instituting meteorological research centers in connection with universities and other centers of education.
>
> The necessity for the issue of suitable handbooks for the purpose of instructing fliers in meteorology.

Truly, the carrying out of these projects is an ambitious program, but it is one that can and should be undertaken and developed, not only in England, but in the United States and other countries as well.

Particularly timely are the portions of the report dealing with trans-Atlantic flight. No definite conclusion is reached as to which route is preferable, but, so far as the Newfoundland fogs are concerned, it is pointed out by Maj. Taylor that these are low in altitude and do not extend far inland. Statements confirming this conclusion are quoted from correspondence with Sir E. Morris and Mr. H. C. Thomson, whose experience of several years in Newfoundland leads them to assert that no difficulty should be encountered in locating a landing field a short distance from the coast that would be practically free from fog.

Other parts of the Reports of Special Committees and of the Main Committee, though of less interest to the meteorologist, contain much valuable information and suggestion to the aviator and will well repay careful reading and study.

[1] Published by his majesty's stationery office, London, 1918. Certain portions of a confidential or secret nature were not included.

METEOROLOGY DURING AND AFTER THE WAR.

By Col. H. G. LYONS,

Acting Director of the Meteorological Office, London.

[Excerpts from a paper read before the Royal Society of Arts on Jan. 22, 1918. Most of the paper was printed in Nature (London), Mar. 6, 1919, pp. 12-16.]

During the past four years and a half of hostilities meteorology has, like many other branches of knowledge, been utilized in naval and military operations to a far greater extent than ever before. Consequently, there are now a large number of officers in the services who have had practical experience of the value of meteorological information when it has been prepared from sufficient data, and by men who have been thoroughly trained in the subject. It is, therefore, highly desirable that full advantage should be taken of the experience which has been gained during the war in order to meet, as adequately as possible, those demands which will be made upon meteorology in the general reconstruction which is now beginning.

In some ways the conditions which prevailed during hostilities were favorable to advances in the subject. Special facilities were given for the rapid transmission of reports; kite-balloons could furnish series of observations at various heights; aeroplanes were available to observe the temperature in successive layers of the atmosphere up to 12,000 or 14,000 feet; the velocity and direction of air-currents up to even 25,000 feet were determined by the bursting of shells fired at high angles; pilot-balloons at perhaps a hundred stations were observed four or more times daily. In these and other ways a vast store of information has been amassed which has already been utilized, but remains available for much more detailed study in the immediate future; and not the least difficult problem will be to reduce the mass of information to a manageable and orderly arrangement.

In the Meteorological Office the policy for some years had been to bring in men who had had a thorough scientific education at a university and to encourage them to devote it to the study of the many problems which meteorology had to offer. This was a great advance from the empirical treatment of the subject, and has been amply justified by the success obtained when this policy has been tested under the conditions of active service.

After the beginning of the war the need for more and more distant stations was felt, and by 1916 reports were being regularly received from Spitsbergen to the North African coast and Cairo, and from Iceland and the Azores to the Russian stations of Petrograd, Nicholaieff, Sebastopol, and Batum.

The supply of daily weather reports and forecasts to the public was stopped, but their preparation was continued actively in the Meteorological Office, where the telegraphic reports which were collected several times daily reached the number of about one hundred, and the information which they contained was compiled on working charts from which the forecasts were prepared. These were issued to the Admiralty, to various dockyards, to the Grand Fleet, various battle squadrons, submarine flotillas, etc., each of which required reports and forecasts adapted to their special needs. Similarly information was supplied to the Naval Meteorological Service for the Royal Naval Air Service, and to numerous units of the Royal Flying Corps, or the Royal Air Force as it afterwards became.

To provide information for aviators in the early morning or for use in preparing plans for the day's operations, it became necessary to take observations in the early hours of the morning, and 3 a. m. was the hour chosen at first, but this was not found to be early enough, and 1 a. m. was finally adopted, making the observing hours 1 a. m., 7 a. m., 1 p. m., and 6 p. m. Thus a continuous 24-hour forecasting service was established, and has been maintained in operation up to the present time, to prepare forecasts and reports four times daily; and to telegraph the observations taken at selected stations to the Meteorological Section at the British General Headquarters in France, and to other stations that required them, as well as to the Meteorological Service of the French Army, and later to that of the American Expeditionary Force.

Under service conditions something simpler, plainer, and more direct in its presentation of the opinions of the trained meteorologists who prepared it than the ordinary daily weather report with its statistical data was needed. Those who had to make use of the daily weather reports were usually far too busy to wish to study the statistical material before accepting the meteorological opinions which were offered to them. They wanted a direct statement of expert opinion which they could make use of in preparing their own plans of action. The desire for such expert assistance was also shown by many requests that forecasts should be expressed in "perfectly simple and non-technical language." To this very reasonable request it is not so easy to accede as it may seem. Such expressions as "a depression advancing from the westward," "a secondary depression developing over the Channel," "an anticyclone spreading northward," are more than mere statements of fact; they convey to all who are acquainted with meteorology much additional information depending on the weather conditions described, which it would take several paragraphs to state simply and in non-technical language.

So far as meteorological conditions could be set out in plain language, this was done in these special daily weather reports, which were issued in the early morning, before noon, and in the afternoon to all who required them; and these were supplemented by special summaries, one of which dealt with the prevailing and the prospective weather conditions on all fronts where military operations were in progress, and another with the weather conditions in the various sea areas around Europe.

It was not difficult to estimate from the working weather chart what sort of forecast the enemy meteorologists would probably make on the assumption that the information from a wide area to the westward of them was not available, and this was done daily as part of the routine of the Meteorological Office. In the case of attacks by enemy aircraft it was fair to assume that his meteorological service considered the conditions to be reasonably favorable; and this was compared with the estimate of his opinion which had been formed here. Occasionally enemy forecasts were available, and these were compared in the same way. Negative evidence is not conclusive, but the impression that we gained was that little if any meteorological information of value was obtained from our area.

Many cases could be cited where operations were undertaken by the enemy which it seemed very unlikely that he would have undertaken had he possessed the information which we had here.

By the spring of 1915 two branches of the Army, the Royal Flying Corps and the Special Brigade, R. E.

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(Chemical Warfare), had decided that they required the cooperation of trained meteorologists who could explain the meaning and the limits of the forecast, answer questions or give advice, and arrange for fuller or more suitable information being furnished when required.

These demands for the provision of trained meteorologists in France led to the formation of a meteorological section as a unit of the Corps of Royal Engineers, which has at first a strength of about 4 officers and 20 non-commissioned officers, but the establishment was repeatedly increased until, when hostilities ceased, it consisted of 32 officers and about 200 other ranks, and provided sections for duty not only in France but also on the Italian and Macedonian fronts, besides a reserve section at home. From a small unit at General Headquarters in France the organization developed until there was a meteorological unit with each army and one with the Independent Force, R. A. F., these units having their groups of observers and pilot-balloon stations reporting to them. The telegraphic weather reports from the stations in the British Isles, as well as those received from a large number of European stations, were at first thrice daily, and later four times daily, telegraphed from the Meteorological Office in London to the Meteorological Section at General Headquarters in France, in order that weather maps might be drawn and forecasts prepared there as might be required. This information was supplemented by data which the Meteorological Section collected from its station on the British front, and also from other parts of France through the French Meteorological Services.

In this way on the western front, and similarly at later dates on the Italian and Macedonian fronts, a network of meteorological stations was built up, which, with the addition of the data and reports furnished by the Meteorological Office, enabled the meteorological officers to supply the information which the different services required for their special purposes, to issue forecasts and weather warnings, and also, as will be seen later, to increase very materially the accuracy of the work of some of the services.

The task of providing the personnel for this military unit was no easy one, for, as has been already mentioned, the staff of the Meteorological Office was small, and outside it there were very few expert meteorologists who were available. At first three of the senior staff of the Meteorological Office received commissions for duty in France, and afterwards a number of men who had a thoroughly scientific education at a university joined the Meteorological Office for longer or shorter periods of training before being posted to the Meteorological Section, and in this way a high-grade scientific staff was formed and maintained. To a training which included especially mathematics and physics was added as much instruction and practice in advanced meteorology as could be given in the time available, and on the basis of such an education the meteorological aspect of the problems was quickly appreciated.

As time went on the scope and number of such reports and warnings steadily increased until there was a regular and continuous flow of information sent out from meteorological offices to various branches of the service for them to utilize as best fitted the operations in hand. The Royal Air Force required forecasts of weather for short periods which it could use for its reconnoitering and bombing squadrons; for day operations reports of the wind direction and velocity obtained from pilot-ballon ascents and high-angle shell bursts were communicated from different altitudes up to 20,000 feet; for night operations information for lower levels sufficed, and the arrangements had to be modified. For high altitudes a central station could supply information adequately, but when data concerning lower levels became important, where the air turbulence set up by friction with the earth's surface became a material factor, the reports were more effectively supplied by local stations where the special conditions could be more effectively studied. For all this the most rapid means of transmission is essential; for the shorter the forecast period, and the more detailed the forecast in its information, the more rapidly must it be placed at the disposal of the aviator if it is not to mislead him. These reports were largely supplemented by telephone inquiries by those interested, and a precision was demanded which was often very difficult and sometimes impossible to attain. Success in answering these inquiries is reached by having as meteorological officers men who have an acquaintance with the physical condition of the region, and also possess such a scientific training that they instinctively proceed from cause to effect, and facts at once fall into their place in their minds. This is very different from the acquired skill of an empirical forecaster, who can never attain the same confidence in his opinion.

In chemical warfare a different set of problems was encountered. Here we are concerned with the movement of air currents close to the surface of the ground, affected by all its irregularities, diverted this way and that by obstacles, and generally in that state of irregular motion known as turbulence in which eddies form, break up, and reform, greatly complicating the conditions. At night, too, when the surface wind may die down to a calm and the ground cools under a clear sky, the colder and heavier air streams down from higher ridges into valleys and low ground. Consequently the direction and velocity of air currents along the front had constantly to be observed and studied in relation to the relief and conditions of each section; so long as the wind was favorable for enemy operations, or even likely to shift into a favorable quarter, observations, reports, and warnings were unceasingly needed.

But, besides the aviators, there are other branches which are vitally interested in the conditions which prevail in the upper air. Projectiles leave the firing point and traverse a considerable thickness of the atmosphere during their flight, reaching an altitude of about 10,000 feet for a 50-second trajectory. In its passage through the air a projectile traverses strata of different temperatures, and consequently of various densities, so that a correction has to be applied to the range tables. On a winter day, when the temperature at the surface is 3° F., the temperature at 3,000 feet, 6,000 feet, and 9,000 feet may be 15° F., 16° F., and 12° F., respectively, so that any correction based on the temperature near the ground would be wrong. Also the wind varies considerably, and often irregularly, both in velocity and direction as the ground is left, so that a correction based on mean conditions here will probably be widely different from that which should be used on any particular occasion.

These considerations led to a much wider application of meteorological information to the practical correction of gunnery than had hitherto been employed, and reports of upper-air temperature and of the velocity and direction of the wind at various altitudes were regularly prepared and transmitted from meteorological stations along the various fronts. This increased application of meteorology to ballistics raises many problems of interest and

importance, which demand for their solution the cooperation of scientific gunnery and meteorological science of the highest order.

To mention another field, the sound-waves which are recorded in sound ranging, that wonderful adaptation of the physical instruments of the laboratory to practical use on the field of battle, traverse the lower layers of the atmosphere, and as higher and higher accuracy was aimed at, it became clear that meteorological observation must be made concurrently and utilized in order to attain the desired precision.

Frequent mention was made during the war of the meteorological efficiency of the enemy's organization and of the very favorable conditions which he experienced during many of his operations; his superiority in these directions was not infrequently assumed. It is not possible to compare the effectiveness and success of the rival organizations until much more information is available and, in the discussion and investigation of past operations, the various contributing factors have been sorted out and duly weighed. No doubt Germany started with a much larger number of men who had received a scientific training in the subject, for professors of meteorology existed at several universities; the appreciation of the subject and its practical value, too, may have been more general among that nation; but, as a personal opinion, I do not believe that it attained a higher standard than our own. Many apparently did not realize that the occurrence of bad weather during operations did not necessarily mean that the commander and his staff had no information regarding the impending weather changes; but weather is only one of many factors which have to be taken into consideration, and it must often be that operations planned and prepared must be carried out whatever the weather may be, though a good forecast may at the last moment enable him to judge whether nearer or more distant objectives are likely to be attained.

There are now four State meteorological services in operation—the Meteorological Office, the Admiralty Meteorological Service, the Meteorological Section, Royal Engineers for the Army, and the Meteorological Service, Royal Air Force of the Air Ministry—and the relations and the means for cooperation between these four services will have to be worked out, and a number of considerations taken into account.

So far as the study of the weather and the issue of forecasts is concerned, short-period meteorology, as it may be called—rapidity of transmission of the observations to the central office, where they are discussed and compared, and of the forecasts, warnings, etc., which are sent from it—is the first essential, and the needs of aviation have only accentuated this. Observations should be in the central office for the forecaster's use not later than one hour after they are taken if he is to get out his reports and warnings early enough to be of effective use to aviators.

Aviation, with its prospect of long-distance communication, has rendered necessary a readjustment of meteorological relations within the Empire. Canada, South Africa, Australia, New Zealand, India, and Egypt and the Sudan have all their well-equipped meteorological services, which include networks of stations so selected as to represent most suitably the different meteorological conditions prevailing in those regions. In each there is a scientific staff studying the problems that arise or affect the economic life of the country. Except as students of the same science, the interests of each service have been somewhat diverse from the nature of the requirements which each had to meet, but in future we must organize the provision of all information that aviation may require; and since aviators are going to pass from continent to continent and from one country to another, uniformity of some kind must be attained in respect of the assistance that meteorology is to give.

The problems that press for early investigation are too numerous to recite, but a few may be mentioned.

The relation of meteorology to gunnery must be continued and the study of the many problems involved carried on by competent men.

The air routes of aerial transport will have to be studied and all the information now available must be sorted out, investigated, and discussed in order that it may be put in the form most suitable for use by airmen. This will demand much additional observing at many places besides the discussion of existing material, but unless this is done as part of a concerted scheme much unnecessary expense will be incurred, and the results will fall far short of what they should be, since all the data must eventually be worked up in connection with that from other places, and if all are not of the same scientific standard they cease to be comparable, and must often be rejected in discussion.

Many of the stations in the Crown colonies can afford most valuable information in this connection if expert meteorologists are available to carry out the work. An observant traveler in Dahomey has remarked upon the presence of a steady northeasterly current at about 6,000 feet to 7,000 feet over the lower currents of the southwestern monsoon of West Africa, and such information, if substantiated and extended, may be of material importance in this region.

While overland observations are numerous, and have been extended by means of *ballons-sondes*, aeroplanes, etc., to very great heights, our knowledge of the atmosphere over the sea is much less complete. By means of ships equipped for the purpose, such observations can be, and have been, made in certain parts, but this line of investigation must be extended if our knowledge is to be adequate.

Besides these more evident needs of aviation there are many problems of great practical importance which merit a closer and more thorough investigation than they have yet received. Among these may be suggested those violent disturbances known as hurricanes and typhoons. Recent theoretical investigations have thrown much light on their nature, and a further study of the evidence which exists should greatly add to our knowledge of them.

Variation of rainfall is always a matter of importance, and in countries where it is barely adequate for agriculture any diminution of it is a serious matter, and such cases call for careful investigation.

The war has given a great impulse to meteorology by showing its possibilities to all, and aviation has made, and is still making, more and more demands upon it for information of every kind.

METEOROLOGICAL SERVICE OF THE ARMY.[1]

By Maj. Gen. G. O. SQUIER, Chief Signal Officer, United States Army.

[Reprinted from "Aeronautics in the United States at the Signing of the Armistice, Nov. 11, 1918." New York, 1919, pp. 26-28.]

In August, 1917, the Chief Signal Officer directed Lieut. Col. R. A. Millikan to organize an Army Meteorological and Aerological Service, the purpose of which was threefold:

(*a*) To provide the American Expeditionary Forces with all the meteorological and aerological information needed.

(*b*) To supply the aviation fields, the coast artillery stations, the ordnance proving grounds, and the gas-warfare service within the United States with such meteorological and aerological data as might be useful to them.

(*c*) To undertake for the first time in the history of the world the problems of mapping the upper-air currents over the United States, the Atlantic, and western Europe in aid of aviation, and particularly with reference to trans-Atlantic flight.

In carrying out the first of these projects, there were selected approximtely 550 men of high qualifications, most of them physicists or engineers, who were given a two months' course in meteorological and aerological theory and observations at College Station, Tex. Three hundred and fourteen of these men were sent overseas where they have been operating as an effective and well-organized branch of the work of the American Expeditionary Forces. In addition to furnishing a general weather forecast for the American Expeditionary Forces, this service has supplied a meteorological unit to each aviation post, each gas-service post, each artillery post, and each sound-ranging post of the American Army in France. Under the effective direction of Maj. [now Lieut. Col.] W. R. Blair, one of the most experienced aerologists of the United States, commissioned for the service from the Weather Bureau, about 20 upper-air stations were established in France and England and a forecast based on data furnished by these stations made regularly to the American Expeditionary Forces.

For the accomplishment of the second element of the program, 28 stations manned by 150 men, all carefully picked at the start and well trained at College Station, have been established for furnishing local data as to either surface or upper-air conditions, or both, to the flying fields, artillery posts, and proving grounds in this country. The largest of these stations is that at the Aberdeen Proving Ground, which is manned by 22 men and furnished to the Bureau of Ordnance all necessary data for the determination of ballistic wind which, in view of the development of high-angle fire, has become altogether indispensable for the construction of range tables needed for obtaining accuracy in the work of the artillery.

In carrying out the third element of the program, 26 meteorological stations were established, placed at carefully selected points over the whole of the United States, which stations have been manned by trained observers who telegraph to Washington each day observations on wind velocities at all altitudes up to 35,000 feet. In one instance these observations have been carried to 65,000 feet. On the basis of these observations, a daily forecast of upper-air winds is now being issued. The use which such forecasts may serve, both in connection with the aviation mail service and ultimately with the trans-Atlantic service, may be seen from the fact that above the level of 10,000 feet, 95 per cent of the winds in both the United States and Europe are from west to east and often attain velocities in excess of 100 miles an hour. On November 6, 1918, at Chattanooga, Tenn., a velocity of 154 miles an hour at an altitude of 28,000 feet was observed. It is because of this easterly direction of these upper air currents that all of the long flights thus far made have been from west to east. The importance of a forecast of such currents for the purpose of long flights will be appreciated as soon as the foregoing facts are understood. An airplane capable of a velocity of 154 miles an hour in still air either would remain stationary or travel at 308 miles an hour depending on whether it was headed into or with a wind of the velocity of that observed at Chattanooga.

All of the aerological work so far mentioned has been done with the aid of theodolites especially designed by Maj. W. R. Blair for this service. Sixty of these have been built for the work in this country and 20 shipped abroad.

The problem of exploring the upper-air currents over the Atlantic was at first thought insoluble on account of the absence of fixed bases, but the Meteorological Service has developed propaganda balloons which already have flown at an average altitude of 18,000 feet from Omaha to New Jersey, a distance of more than 1,000 miles. The success of the project now has made possible the mapping of the upper-air highways across the Atlantic, for arrangements are being made to send up from both coastal stations and from trans-Atlantic steamers these long-range balloons designed for from 2,000 to 3,000 mile flights, and adjusted to maintain a constant altitude and to drop in Western Europe their records of average winds in these heretofore unchartable regions. The importance of this work for the future of aviation needs no emphasis.

The success which the Meteorological Service has attained would have been wholly impossible had it not been for the intimate and effective cooperation which has been extended to it in all of its projects by Director C. F. Marvin and the entire staff of the United States Weather Bureau.

[1] Cf. "A Signal Corps School of Meteorology," MO. WEA. REV., Dec., 1918, 46:560-562. More extended accounts of war meteorological work of the Weather Bureau, Signal Corps, and Naval Aviation Service will be published in an early number of the REVIEW.—ED.

INFLUENCE OF WEATHER ON MILITARY OPERATIONS.

[Bibliography.]

From the beginning of the war, Prof. R. De C. Ward collected carefully the press and other reports which mentioned the influence of weather on military operations. These he brought together into 19 very interesting articles which appeared in Popular Science Monthly (now Scientific Monthly), the Journal of Geography, the Journal of the Military Service Institution, and the Scientific Monthly from 1914 to 1919. Some brief abtracts of these papers have appeared in Science,[1] Nature,[2] and elsewhere, but no abstract can do justice to the detailed originals. Therefore, instead of trying to present a summary of these papers, it is thought best to present the bibliography

[1] Cf. Science, June 30, 1916, N. S., vol. 53, pp. 934-935.
[2] Cf. Nature, Aug. 29, 1918, vol. 101, pp. 514-15.

(prepared by Miss M. Welch), especially since most of the articles are in readily accessible journals.

The weather factor in the great war. [Title varies.] (Popular sci. monthly, N. Y. v. 85. Dec. 1914. p. 604–613; Journal of geography, Madison, Wis. V. 13. Feb., Mar., June, 1915. p. 169–171; 209–216; 315–317. V. 14. Nov., 1915; June, 1916. p. 71–76; 373–384. V. 15. Nov., 1916; Apr., 1917. p. 79–86; 245–251. V. 16. Oct., Nov., 1917; Apr. 1918. p. 47–51; 86–90; 291–300.)

Weather and the war. (Journal of the military service institution, Governor's Island, N. Y. v. 61. July–Aug. 1917, p. 43–50; Sept.–Oct. 1917, p. 145–155; Nov.–Dec. 1917, p. 293–302.)

Weather controls over the fighting in the Italian war zone. (Sci. monthly, N. Y. v. 6, Feb., 1918. p. 97–105.)

Weather controls over the fighting in Mesopotamia, in Palestine, and near the Suez Canal. (Sci. monthly, N. Y. v. 6, Apr., 1918. p. 289–304.)

Weather controls over the fighting during the spring of 1918. (Sci. monthly, N. Y. v. 7. July, 1918. p. 24–33.)

Weather controls over the fighting during the summer of 1918. (Sci. monthly, N. Y. v. 7. Oct. 1918. p. 289–298.)

Weather controls over the fighting during the autumn of 1918. (Sci. monthly, N. Y. v. 8. Jan., 1919. p. 1–15.)

In *The Windsor Magazine* (London), a British author, E. D. Ushaw, has published on the same subject from somewhat different sources. See extensive quotation in *The Literary Digest* (New York), Mar. 29, 1919, pp. 88, 91 and 94.—C. F. B.

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION.

By C. G. ABBOT,

Assistant Secretary of the Smithsonian Institution.

By invitation of Prof. Marvin, Chief of the United States Weather Bureau, the Smithsonian Institution will communicate from time to time, as received, the measurements of the solar constant of radiation which are being made by its observers at Calama, Chile. The present paper gives in Table 1 the values which have been received hitherto from the station, beginning with July 27, 1918.

The values are being communicated daily by telegraph from Calama to Buenos Aires and by letter to Rio de Janeiro, as the meteorological services of Argentina and Brazil are conducting a test of their value for purposes of forecasting. The usefulness of the solar constant results for this purpose is not so firmly established as to warrant the expense of telegraphing the results to the United States, but in order to put them as speedily as feasible before meteorologists, Prof. Marvin has thought good to arrange for their regular publication in the MONTHLY WEATHER REVIEW.

It is to be understood by the reader that these values are preliminary, and subject later to detailed revision and occasional change as they will be published in extenso by the Smithsonian Institution; but the changes which will be made in such revision will probably be small, and oftentimes no change at all will occur.

The solar constant of radiation as here defined is the intensity of the solar radiation as it would be outside of the earth's atmosphere at mean solar distance. It is determined by the use of the spectro-bolometer and pyrheliometer in the manner described by the writer in the MONTHLY WEATHER REVIEW for January 1919 (vol. **46**, pp. 1–3), where an account of the South American Expedition of the Smithsonian Institution is given.

In the following publications we shall give values of the solar constant in calories per square centimeter per minute, values of the atmospheric transmission coefficient at wave length 0.50 microns, indications of the trustworthiness of the results, indications of the humidity of the air prevailing at the earth's surface and also as integrated through the whole path of the earth's atmosphere between the observer and the sun, and, finally, notes as may be desirable, explanatory of the results of individual days.

In estimating the trustworthiness of the individual values, the following criteria are employed: First, as to the internal evidence of the goodness of the observations. This depends upon the mutual support offered by the six bolographic observations of a given day. If the transparency of the atmosphere remains unchanged during the several hours required to determine it, the logarithms of intensities at each of the several wave lengths where measurements are made in the solar spectrum should be proportional to the air mass traversed by the solar beam in the atmosphere. In other words, the logarithmic plot whose ordinates are logarithms of intensity and whose abscissæ are air masses (or roughly secants of the sun's zenith distance) should approach a straight line for each individual wave length in the spectrum. Noting the proportion of 40 different wave lengths for which this criterion is well supported on a given day, the observers draw their conclusion as to whether the constancy of the transparency for the day was excellent, very good, good, or poor, and they indicate this judgment by the letters E, VG, G, and P. Sometimes they further qualify these characters by the symbols + and −. Thus E− indicates a day on which the logarithmic plots were generally very straight, but not quite as satisfactory as for a day marked E. When the mark given is E+, it indicates that no improvement on the merit of the day from the point of view of the logarithmic plots could reasonably be hoped for. Days marked G−, or P are entitled to little weight unless the defect of the observations should be explainable by reason of earthquakes or magnetic storms which, while they might introduce irregularities in the spectrobolographic determinations, would yet be independent of variations of the transparency of the air.

It is a weakness of the method that the determinations of the atmospheric transmission require several hours of unchanged transparency of the air. We are developing an empirical method, based upon the full spectro-bolometric method, by means of which we hope to shorten the period required to determine the solar constant to a few minutes, and it is possible that the application of this new method may enable us to materially improve the results.

Further conclusions as to the merits of individual determinations are based upon visual examination of the sky during the period of observation. If cirrus clouds are seen in the same quarter of the sky as the sun, and especially if they spring up during the observations, or pass off during the observations, this fact tends to weaken the day's result. Also, if there has been during the days immediately preceding, or if there follows in the immediately succeeding days, a period of cloudiness, this weakens the result. Special considerations of this character should be taken into account in the estimation of the merit of the day. It is regretted that the sky has

not proved as free from clouds at Calama as available meteorological observations led us to expect before we established the solar station there.

Further considerations are based upon the degree of humidity prevailing and on the substantial constancy or variability of it during the observations. Three columns are devoted to humidity. The first, designated by ρ/ρ_{80} indicates the relative intensity in the middle of the water vapor band called by Langley. ρ, σ, τ, as compared with the intensity indicated by the smooth curve over the top of the band, or in other words as it would be observed by the bolometer if the humidity were zero. This ratio for ρ/ρ_{80} gives thus an index of the integrated humidity prevailing between the observer and the outside limit of the atmosphere in the direction of the sun.

The second and third columns of humidity give the observed vapor pressure and relative humidity prevailing at the station as measured by the Assmann ventilated psychrometer. All humidity values given relate to the air mass where secant z equals 3.0.

TABLE 1.—*Solar constant, atmospheric transmission, and atmospheric moisture values, measured at Calama, Chile, July, 1918, to January, 1919, inclusive.*

Date, A. M. or P. M.	Solar constant.	Grade.	Transmission coefficient at 0.5 micron.	Humidity (Air mass=3.). ρ/ρ_{80}	Humidity (Air mass=3.). V. P. cm.	Humidity (Air mass=3.). Rel. hum. %.	Remarks.
July 27, A. M.	1.944	VG...	0.862	0.655	0.10	14	
28, A. M.	1.901	VG+.	.852	.587	.14	20	
29, A. M.	1.899	VG...	.857	.590	.15	22	
30, A. M.	1.929	VG−.	.835	.595	.15	22	
31, A. M.	1.932	VG+.	.859	.538	.16	23	Cirri in south and west.
Aug. 1, A. M.	1.945	VG+.	.875	.627	.11	18	
3, A. M.	1.966	E.....	.868	.672	.09	16	Some cirri.
4, A. M.	1.948	VG...	.845	.673	.08	14	
5, A. M.	1.954	E−...	.865	.705	.06	11	
6, A. M.	1.972	E−...	.862	.675	.06	11	
7, A. M.	1.948	E.....	.870	.652	.10	16	
8, A. M.	1.955	VG+.	.882	.677	.10	13	
10, A. M.	1.954	E−...	.866	.619	.13	19	
11, A. M.	1.965	VG−.	.868	.656	.09	13	
12, A. M.	1.959	E.....	.866	.745	.08	11	
14, P. M.	1.925	VG+.	.858	.559	.22	15	
15, A. M.	1.947	VG...	.855	.595	.15	23	
16, A. M.	1.987	VG+.	.853	.705	.07	11	
17, A. M.	1.888	VG+.	.874	.552	.08	15	Scattered cirri and cumuli at 11 a. m. Almost entirely overcast by 2 p. m.
19, A. M.	1.948	E−...	.871	.457	.22	26	Low cumuli in east. Small floating clouds high in south.
20, A. M.	1.940	E−...	.860	.574	.21	26	
21, A. M.	1.995	VG+.	.866	.814	.07	9	
22, A. M.	1.953	E.....	.858	.726	.06	10	
23, A. M.	1.979	E+...	.859	.739	.08	12	
24, A. M.	1.932	G.....	.850	.705	.09	16	
25, A. M.	1.968	E−...	.856	.693	.07	12	
26, A. M.	1.949	VG+.	.865	.647	.09	12	
27, A. M.	1.955	E.....	.865	.677	.11	13	
28, A. M.	1.894	E−...	.862	.599	.12	16	
29, A. M.	1.954	VG+.	.832	.523	.14	19	
30, A. M.	1.953	VG+.	.828	.474	.20	29	
31, P. M.	2.018	G+...	.817	.444	.37	21	Considerable cumulus in north and east. Cirri near sun latter part of observation.
Sept. 1, A. M.	1.980	VG−.	.855	.468	.23	27	
6, A. M.	1.937	VG+.	.845	.381	.38	61	Bank of cumulus in east, also in northwest.
7, A. M.	1.951	E−...	.860	.542	.18	24	
8, A. M.	1.911	E.....	.862	.705	.09	15	
9, A. M.	1.931	VG−.	.866	.698	.07	11	
14, A. M.	1.931	VG+.	.866	.531	.29	41	Patches of cirrus not far from sun.
15, A. M.	1.935	VG−.	.863	.621	.15	27	
16, A. M.	1.960	E.....	.845	.747	.06	10	
17, A. M.	1.951	VG+.	.861	.764	.05	8	
18, A. M.	1.958	VG...	.851	.691	.09	15	
19, A. M.	1.943	E.....	.863	.728	.10	15	
21, P. M.	1.937	E.....	.858	.423	.30	14	Considerable cirrus in west and east.
22, A. M.	1.938	E.....	.851	.406	.19	25	Considerable cirrus.
26, A. M.	1.950	E−...	.856	.697	.08	12	Cirri low in north and east.
27, A. M.	1.924	E−...	.854	.667	.13	20	
28, A. M.	1.949	E.....	.833	.761	.12	19	
29, A. M.	1.978	VG+.	.848	.683	.08	13	
30, A. M.	1.936	VG+.	.835	.738	.07	6	Cirri in east.

TABLE 1.—*Solar constant, atmospheric transmission, and atmospheric moisture values, measured at Calama, Chile, July, 1918, to January, 1919, inclusive*—Continued.

Date, A. M. or P. M.	Solar constant.	Grade.	Transmission coefficient at 0.5 micron.	Humidity (Air mass=3). ρ/ρ_{80}	Humidity (Air mass=3). V. P. cm.	Humidity (Air mass=3). Rel. hum. %.	Remarks.
Oct. 1, A. M.	1.992	VG+.	.849	.716	.08	13	Low cirrus in south.
2, A. M.	1.932	E−...	.850	.668	.10	16	
3, A. M.	1.936	E.....	.855	.740	.07	11	
4, A. M.	1.942	E.....	.848	.745	.06	10	
5, A. M.	1.963	VG...	.853	.712	.06	9	
6, A. M.	1.980	E−...	.855	.699	.08	12	
7, A. M.	1.929	E−...	.855	.725	.07	12	
8, A. M.	1.945	E.....	.850	.677	.08	13	
9, A. M.	1.941	E−...	.851	.712	.06	12	
10, A. M.	1.950	VG+.	.862	.676	.07	8	
11, A. M.	1.865	VG...	.858	.558	.08	11	Cirri all around sky.
13, P. M.	1.951	VG...	.855	.461	.29	13	Cloudiness in east. Scattered cirri in north, south, and low in west.
14, P. M.	1.946	G+...	.865	.478	.35	15	Cumuli in east. Line of small cirro-cumuli in southwest.
15, A. M.	1.957	G−...	.855	.445	.18	24	Bank of cirrus in northeast.
16, A. M.	1.941	G−...	.850	.463	.29	41	
17, A. M.	1.935	VG...	.853	.455	.23	31	Considerable cirrus in northeast.
18 A. M.	1.939	VG....	.848	.713	.09	11	
19, A. M.	1.908	VG+.	.863	.627	.13	15	Cirri in north.
21, A. M.	1.958	VG+.	.860	.544	.18	24	Cirri in northeast.
25, P. M.	1.882	VG−.	.855	.418	.38	19	Scattered cirri.
28, A. M.	1.903	VG+.	.861	.488	.23	33	Cirri in north and east.
29, A. M.	1.928	VG...	.852	.525	.17	27	
30, A. M.	1.927	G.....	.858	.542	.17	29	
31, A. M.	1.901	VG...	.860	.493	.21	33	Cirri in northeast.
Nov. 1, A. M.	1.876	VG...	.871	.645	.15	22	Cirri low in northeast.
5, P. M.	1.921	VG−.	.855	.500	.22	10	Cirri in east.
6, A. M.	1.893	G.....	.804	.548	.17	24	Low cirri in west.
7, A. M.	1.956	VG+.	.862	.622	.14	18	Cirri in east.
8, A. M.	1.969	VG+.	.845	.613	.15	18	
9, A. M.	1.951	VG−.	.847	.512	.16	23	Scattered cirri.
12, P. M.	1.954	E−...	.855	.641	.24	11	Cirrus in north and east, with two patches below sun in west.
13, A. M.	1.941	G+...	.850	.575	.19	22	Some cirri in east.
15, P. M.	1.969	VG−.	.829	.454	.32	15	Cirri in east, but disappearing.
16, A. M.	1.924	VG...	.848	.493	.23	30	Some cirri in northeast.
17, A. M.	1.934	E.....	.845	.507	.21	28	Low bank of cirrus in northeast.
18, A. M.	1.945	E−...	.854	.469	.31	31	Thick bank of cirrus in east below sun.
19, A. M.	1.931	VG...	.839	.400	.28	31	
20, A. M.	1.963	E−...	.801	.348	.36	47	Cirri in north and east More forming continually.
21, P. M.	1.945	VG−.	.831	.446	.33	16	
22, P. M.	1.962	E−...	.840	.467	.31	15	Cirrus in north.
23, P. M.	1.972	VG−.	.827	.464	.34	17	Cirri in north and east—increasing.
25, A. M.	1.990	E−...	.822	.351	.43	56	Cirri in north, southwest, and low in east.
26, A. M.	1.924	VG−.	.829	.330	.28	36	Cirro-cumuli in east and west.
27, P. M.	1.925	VG...	.848	.506	.24	13	Cumuli in east and south.
28, P. M.	1.917	G+...	.848	.502	.28	12	Floating clouds in southwest and in east.
29, P. M.	1.962	VG...	.848	.543	.26	13	Few cumuli in east.
30, A. M.	1.926	VG...	.862	.511	.18	23	
Dec. 1, A. M.	1.964	E−...	.853	.539	.21	24	Few patches of cirrus in north.
2, A. M.	1.954	E.....	.853	.546	.21	26	
3, A. M.	1.967	E.....	.874	.590	.17	22	
4, A. M.	1.999	VG...	.854	.687	.10	13	Cirrus disappearing in northeast.
5, P. M.	1.986	G−...	.833	.591	.28	14	Scattered cirri.
6, P. M.	1.954	P+...	.827	.447	.32	15	
7, A. M.	1.983	E−...	.832	.461	.26	24	
8, A. M.	1.925	E−...	.828	.333	.34	34	Thin floating clouds in south, southeast, and southwest.
9, P. M.	1.939	VG+.	.832	.392	.35	15	Floating clouds low in east.
10, A. M.	1.947	E.....	.844	.453	.28	25	
11, A. M.	1.943	E.....	.855	.532	.19	20	Few patches of cirrus in northwest.
12, A. M.	1.951	VG+.	.852	.551	.17	17	Cirri moving rapidly from northwest.
13, P. M.	2.013	VG+.	.830	.491	.27	11	Cirri scattered over sky with large bank in west.
22, A. M.	1.925	VG+.	.842	.359	.52	51	Cirrus in east and northeast, disappearing.
23, A. M.	1.984	E−...	.851	.433	.37	42	
26, A. M.	1.952	E−...	.834	.397	.31	36	
27, A. M.	1.950	E−...	.852	.532	.25	30	Small patch of cirrus in north.
28, A. M.	1.948	E−...	.857	.522	.19	23	Cirrus scattered over large part of sky.
31, A. M.	1.942	E.....	.858	.429	.35	41	
1919.							
Jan. 1, A. M.	1.960	E−...	.854	.433	.21	28	
2, A. M.	1.969	E−...	.853	.446	.23	27	Bank of cirrus in northeast.
3, A. M.	1.974	E−...	.848	.428	.30	36	Bank of cirrus in northeast.

TABLE 1.—*Solar constant, atmospheric transmission, and atmospheric moisture values, measured at Calama, Chile, July, 1918, to January, 1919, inclusive*—Continued.

Date, A. M. or P. M.	Solar constant.	Grade.	Transmission coefficient at 0.5 micron.	Humidity (Air mass=3). ρ/ρ_{sa}	Humidity (Air mass=3). V. P. cm.	Humidity (Air mass=3). Rel. hum. %.	Remarks.
Jan. 6, A. M.	1.890	VG+	.840	.270	.48	45	
8, A. M.	1.899	VG+	.845	.336	.39	39	Cirri all around horizon.
11, A. M.	1.941	E−	.855	.425	.41	43	
12, A. M.	1.888	E	.870	.568	.38	38	Some cirri in east and north
14, A. M.	1.963	VG−	.868	.637	.26	32	Considerable cirrus in east and south.
16, A. M.	1.948	E−	.841	.371	.45	50	Considerable cirrus in east and north, with large patches in west.
17, P. M.	1.939	VG−	.851	.423	.39	16	Considerable cirrus in east, but disappearing.

TABLE 1.—*Solar constant, atmospheric transmission, and atmospheric moisture values, measured at Calama, Chile, July, 1918, to January, 1919, inclusive*—Continued.

Date, A. M. or P. M.	Solar constant.	Grade.	Transmission coefficient at 0.5 micron.	Humidity (Air mass=3). ρ/ρ_{sa}	Humidity (Air mass=3). V. P. cm.	Humidity (Air mass=3). Rel. hum. %.	Remarks.
Jan. 18, A. M.	1.978	VG−	..858	.495	.31	32	Streaks of cirrus low in west.
19, A. M.	1.952	E−	.873	.630	.23	28	
20, A. M.	1.960	VG+	.874	.445	.48	51	
21, A. M.	1.932	VG+	.854	.430	.39	42	
22, A. M.	1.939	E−	.852	.384	.38	40	Thin cirri on north and cumuli at horizon in east.
23, A. M.	1.930	E−	.847	.344	.39	38	Patch of cirrus in southeast
24, A. M.	1.906	E−	.836	.305	.40	48	
25, A. M.	1.969	VG+	.822	.311	.58	61	Cirrus low in west.
29, A. M.	1.926	E−	.857	.387	.51	51	Small patch of cirrus near horizon in east.

THE DIRECTION OF ROTATION OF CYCLONIC DEPRESSIONS.

By J. S. DINES, Meteorological Office, London.

[Dated: Jan. 16, 1919.]

In a recent number of Nature (Dec. 12, 1918) I called attention to the fact that there is no dynamical reason why cyclonic circulation should not take place in the opposite direction to that commonlye xperienced. That is, clockwise circulation round a low pressure center may theoretically occur in the Northern Hemisphere and counter clockwise in the Southern. This result is apparent on consideration of the gradient wind equation connecting the velocity V with the pressure gradient γ.

The equation is

$$\frac{\gamma}{D} = 2\omega . V . \sin\lambda + V^2 . \cot \rho/R$$

where D is density, ω angular velocity of the earth, λ latitude, R radius of the earth and ρ angular radius of curvature of the air path.

This equation being a quadratic in V has two roots, a positive one which corresponds with the normal circulation and a numerically larger one of negative sign corresponding with reversed circulation. Both these roots represent a stable state and therefore the only reason which appears to exist to prevent the reversed cyclone is that it can not get started, the rotation of the earth inevitably causing counter clockwise rotation to be set up in the Northern Hemisphere immediately any low pressure center is formed.

In a circular cyclone of the reversed type if the pressure gradient remain constant with increasing distance from the center the wind velocity will become very great in the outer regions, where ρ is large. It seems to follow that in such a cyclone the pressure gradient must fall off rapidly from the center and the steep gradient often found over large areas in normal cyclones could not occur in the reversed type.

In the case of circulation round a high pressure center the positive sign in the above equation is replaced by a minus sign. Two roots for V again appear, but in this case both are of the same sign and therefore both correspond with clockwise rotation in the Northern Hemisphere.

It seems possible that the reversed cyclone may be formed on a small scale by accidental causes such as an eddy set up round a precipitous headland, and perhaps under favorable conditions such a whirl might develop into a tornado, retaining its clockwise rotation. Little attention seems to have been devoted to the direction of rotation of tornados and evidence on the point is sometimes conflicting. Thus in the MONTHLY WEATHER REVIEW for April, 1918, a whirlwind at Pasadena, Calif., was described and Prof. E. Ellerman, of Mount Wilson Solar Observatory, recorded his impression that the rotation was clockwise.

The author of the paper apparently did not consider this evidence conclusive and the question remains open. One would like to impress strongly on observers of such phenomena the importance of taking careful note of the direction of rotation. A study of the damage along the storm track should afford conclusive evidence in the majority of cases. In this respect observers in the United States are in a much more favorable position than those in this country, owing to the extreme rarity of such phenomena in Europe.

An interesting fact which emerges from a study of the roots of the equation is that whereas in the case of a large depression the velocity in the reversed cyclone is decidedly greater than in the normal type for any given gradient, in small whirls of the tornado type it is almost the same in either direction. There is thus no reason to think that with a given decrease of barometric pressure at the center the reversed tornado would be appreciably more or less destructive than the counterclockwise type.

It has probably been generally recognized that a small whirl can rotate in either direction, but the fact that the same principle applies to a large cyclonic depression appears to have escaped attention.

DISCUSSION.

While the main point of Mr. Dines's paper is the proof of the dynamic possibility and a call for observations of reverse cyclones, the results of a further discussion of this matter in the Central Office of the Weather Bureau may be of interest.

A "gradient wind," by definition, flows in a direction perpendicular to the gradient and at such a velocity that two of the three forces, (1) gradient, (2) deflective effect of the earth's rotation, and (3) centrifugal force, acting

in one direction are numerically equal to the third, acting in the opposite direction. Taking symbols used in the United States [and assigning to each a value used by Dines (Nature, Dec. 12, 1918, p. 284)], namely,

ρ for air density [1,217 gm. per cu. m.],

$\frac{dp}{dn}$ pressure gradient [1 mb. per 100 km.],

ω velocity of angular rotation of the earth [.00007292],

v wind velocity [to be determined],

ϕ latitude [55° N.],

and r radius of curvature of the wind path as projected horizontally on a plane tangent to the earth's surface at the center of wind-path curvature [334 km.],

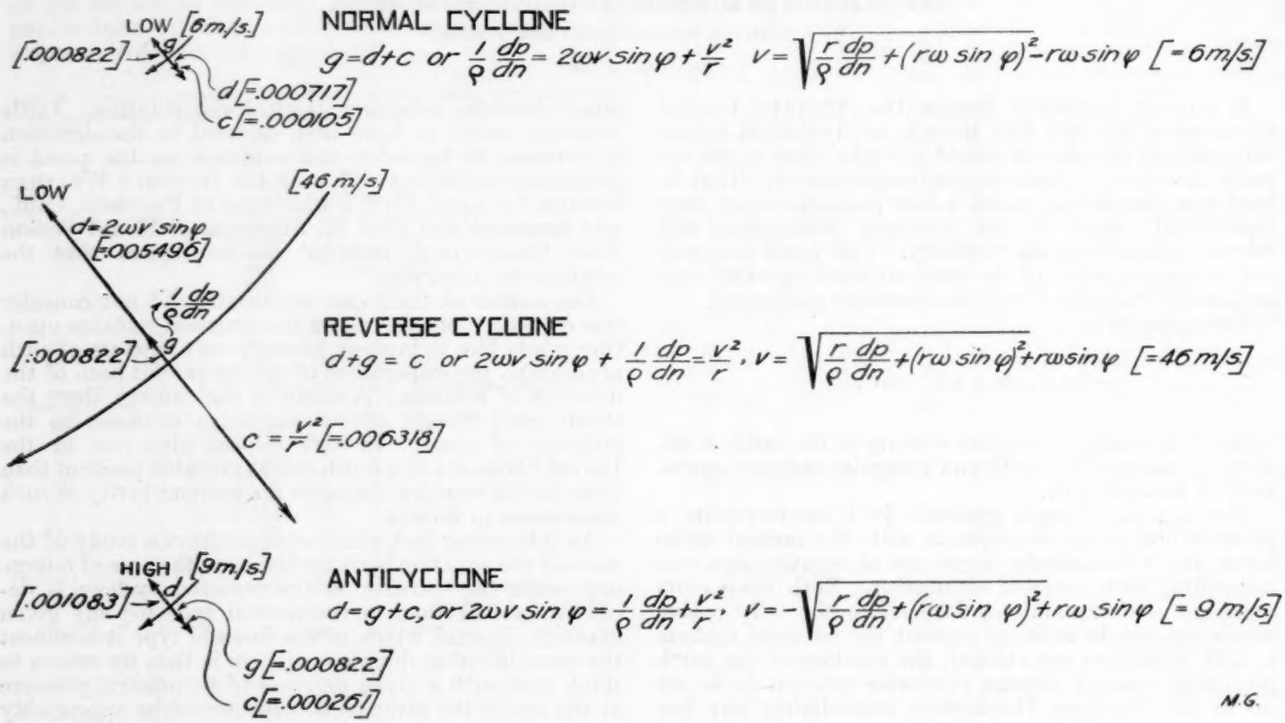
the gradient force, g, is $\frac{1}{\rho}\frac{dp}{dn}$, [.000822],

the deflective effect of the earth's rotation, d, is $2\omega v \sin.\phi$ [.0001195v],

and the centrifugal force, c, is v^2/r [.000003v^2].

their interferences, thus, would be more likely to make counterclockwise whirls than the reverse.

What is the condition of relatively weak clockwise whirls? The reverse cyclone has the deflective and gradient forces toward the inside of the curve equal numerically to the very large centrifugal force toward the outside ($d+g=c$; see fig.); and it is only at high velocities that this centrifugal force can be large enough to equal both the deflective force and the gradient. At smaller velocities the centrifugal force is always less than the deflecting force, and so, to maintain the equation, the centrifugal force must have the gradient force acting with it to keep the wind on a given curved path ($d=c+g$; see fig.). In other words, there would have to be a high instead of a low pressure center on the inside of the curve. Weak clockwise impulses would, therefore, be associated with anticyclones instead of cyclones.—*C. F. Brooks.*



Let us consider these in the normal cyclone (counterclockwise in the Northern Hemisphere), the reverse cyclone (clockwise in the Northern Hemisphere), and the anticyclone, using, for illustration, diagrams drawn to correspond numerically to the values assigned above.

The given latitude, gradient, and radius of curvature in Dines's example would thus require a wind of 6 m./s. in the counterclockwise cyclone and one of 46 m./s. in the clockwise. Even if the gradient should approach zero the velocity requisite to keep the clockwise cyclone going would not fall below 40 m./s.

Since with ordinary gradients and radii of curvature the velocity necessary to maintain a clockwise cyclone is so high, it is obvious why such a reverse cyclone does not get started on a scale larger than a dust whirl or possibly a tornado. Tornadoes are so generally counterclockwise (1) because the necessary initial impulse does not need to be so great to start one in this direction as in the other, and (2) because in tornado regions there is the south wind on the east and the north wind on the west;

ADDITIONAL NOTE ON CLOCKWISE AND COUNTERCLOCKWISE CYCLONIC MOTIONS WITH APPLICATION TO THE FLIGHT OF AIRCRAFT.

Meteorologists easily perceive the slight possibilities that the clockwise motions, shown in Mr. Dines's note to be dynamically possible, can actually get agoing and be sustained on any considerable scale in nature. Nevertheless, no such limitations arise in the case of the flight of airplanes, and with a trifling alteration in one term the equations for the atmospheric motions become fully applicable to the flight of birds and aircraft. It may, therefore, be interesting to examine the results to which these considerations lead.

The basic equation governing all motions of bodies moving horizontally at a uniform velocity in curved paths over the earth's surface is:

$$\frac{mv^2}{r}=Fm\pm fm \qquad (1)$$

in which m is the mass of the body; v its velocity; r the

momentary radius of curvature of the path (neglecting the curvature of the earth); F, taken positive in all cases, is any reaction or resultant of the forces per unit mass of the body and arising within the aircraft (a rudder reaction or component of the sustaining air pressure, for example) which acts to turn the flight of the craft to the right or left as may be desired; and the quantity f is here the familiar expression for the deflective force per unit mass of the earth's rotation on a body moving at velocity v in latitude ϕ, viz,

$$2v\omega \sin \phi$$

In the Northern Hemisphere the plus sign in (1) will apply in all cases in which the aircraft turns to the right or clockwise, while the minus sign represents counterclockwise or left-hand turns, with vice versa effects in the Southern Hemisphere.

Our present purpose is to examine the results required to satisfy equation (1) under conditions which may ordinarily occur. Solving for r we get for forces on unit mass

$$r = \frac{v^2}{F \pm f} \tag{2}$$

Confining attention to velocities of 40 meters per second at latitude 50 we have for r in meters

$$r = \frac{160000}{F \pm .4469 \text{ dynes}} \tag{3}$$

plus for right-handed, minus for left-handed turns.

Solving equation (1) for v we get:

$$v = \sqrt{F r + (r\omega \sin \varphi)^2} \pm r\omega \sin \varphi \tag{4}$$

plus for right-hand and minus for left-hand turns.

For a left-hand turn of a given radius, we see from (2) that F will require to be greater, by nearly one dyne (0.893 dyne) per gram of mass than for a right-hand turn, at the same velocity.

This may be a matter of some consequence because when an airplane swings into a turn with normal bank, the forces F and the weight of the craft are sine and cosine components of the sustaining air pressures. Accordingly, the smaller the force F the more completely the weight of the machine is supported and the less the loss of altitude, which is unavoidable in any case.

Applied to gliding, equation (4) indicates that the glide may be prolonged by executing a long turn to the right rather than to the left. For maximum effect, F must become zero and involve no banking, thus affording maximum support with $v = 2r\omega \sin\phi$. To execute the same glide in a left-hand turn, the value of F would require to be $2f$, accompanied by corresponding banking and loss of sustaining effort.

When a machine is climbing under a given expenditure of power and along a curved flight, the ascent will be more rapid clockwise than counterclockwise.

When a pilot sets out to steer a straight-away course by compass, for example, he always finds himself, even in quiet air, headed away from course in a few minutes. The force F, without his knowledge or intention, has turned the machine to the right or left as the case may be. What are the probable values of F in such cases?

Let us assume the pilot disregards deviations from course that are less than one-quarter point of the compass, say, about 3°. Also, assume that on the average he must rectify his course once every 60 seconds, that is, the forces $F+f$ turn his craft 3° from course every 60 seconds.

From these data it is easy to show that for right-hand turns at 40 meters per second, latitude 50°, F must be $6.812\,f$, and for left-hand turns, $8.812\,f$, in which, under the assumed conditions $f = 0.447$ dynes. F and f, it must be remembered, are forces per gram of moving matter.—*C. F. Marvin.*

WEATHER MAPS IN LONDON NEWSPAPERS.

On January 1 the Morning Post [and later the Times and Daily Telegraph] commenced the publication of the daily weather chart prepared by the Meteorological Office from the 6 p. m. observations. The area included extends from Iceland in the northwest to Corsica in the southeast, the British Isles having a central position and the west of continental Europe, from Scandinavia to the Pyrenees being shown. Isobars are given for intervals of 5 millibars, and the lines are numbered at one end with the pressure in millibars, at the other with the height of the mercurial barometer in inches and hundredths. As the map extends across two columns it is very clear and legible, a great advance on any previous presentation of a weather chart in a British newspaper.

In introducing the new feature the Morning Post, under the heading of "A fascinating daily study," started a series of meteorological articles with the happy quotation from Ruskin:

"While the geologist yearns for the mountain, the botanist for the field, and the mathematician for the study, the meteorologist like a spirit of a higher order than any, rejoices in the kingdom of the air."

The writer understands that a new era in public appreciation of meteorology began with the armistice, and he says: "In all educational establishments, from the universities, through the training colleges, down to the elementary schools, familiarity with the daily Weather Map, and its indications, has now become an imperative necessity. Lectures based upon the many erroneous theories of pre-Weather Map days which are found in most textbooks, and illustrated by diagrams of a generation or half a century ago, are out of date—they are the dried-up, lifeless bones out of which there comes no sustenance. What is now required is the living thing, something that appeals to and interests the scholar because he feels that he is being taught to appreciate what he is experiencing at the moment. This living thing is the Weather Map which a very large proportion of the readers of the Morning Post will have served up with breakfast every morning, and in more distant regions by midday."[1]

The Post and Times both give a description of the general conditions prevailing at 6 p. m., together with the changes then in progress and their probable effect on the weather conditions likely to be experienced over the British Isles during their course. The needs of aviation are also provided for, and a table is given each day in the Times showing the direction and velocity of the wind at 2,000, 5,000, 10,000, and 15,000 feet above the ground.

This information as now supplied is far more complete than was possible in the early days of the war, and should help to stimulate an intelligent interest in meteorological matters among the general public.

Wireless reports from ships out at sea are, it is understood, to be added to the reports as soon as the new service is organized.[2]

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[1] From Symons's Met'l Mag., Feb., 1919, 54: 1-2.

[2] Quart. Jour. Roy. Met'l Soc., London, Jan., 1919, vol. 45, p. 83. See also Nature, London, Jan. 30, 1919, p. 427, and Sym. Met'l Mag., Mar., 1919, p. 19.

CONGRESS OF SCANDINAVIAN GEOPHYSICISTS IN GOTHENBURG AUGUST 28–31, 1918.

By HANS PETTERSSON, General Secretary.

[Dated: Gothenburg, Nov. 27, 1918.]

At the invitation of Dr. G. Ekman, Prof. O. Nordenskjöld, Prof. O. Pettersson and other scientists of Gothenburg, Sweden, a highly representative congress of about 50 Danish, Norwegian, and Swedish geophysicists met in that city during the last days of August this year. Representatives from Finland had also been invited but were unable to be present.

At the opening meeting Prof. Hildebrandsson, of Upsala, was unanimously elected president, supported by three vice presidents, viz, Director Ryder (Denmark), Prof. Bjerknes (Norway), and Prof. Nordenskjöld (Sweden); General Secretary, Dr. Hans Pettersson.

Prof. Bjerknes, of Bergen, opened the first general meeting with a paper on weather forecasting, describing a new and most successful method of short-range prognostics for agricultural purposes established in western Norway during the summer 1918. [Published pp. —, —, of this REVIEW.]

During the following days meetings were held, partly general and partly by sections. In all, 30 papers were read, many of these of very great interest.

One afternoon was devoted to the aurora borealis phenomenon, a forenoon to prognostics, and the last afternoon was occupied by very animated discussions of future Scandinavian cooperation within different branches of the geophysical science.

Finally a number of resolutions were moved and adopted by the congress in pleno and a committee formed with the object of calling together a second congress in due time.

Abstracts of the papers read before the congress will shortly be published.

RESOLUTIONS ADOPTED BY CONGRESS.

I. In favor of an extension of the existing system of simultaneous photographic altitude measurements of the aurora borealis started by Prof. Störmer, to comprise the whole of Scandinavia during the winter 1918–19. (Moved by Prof. Störmer, of Christiania.)

II. In favor of the plan proposed by Prof. de Geer that measurements of the yearly deposits of loam occurring in lakes blocked by ice and in shallow bights, which derive from the melting of Scandinavian and arctic glaciers, should be carried out in connection with de Geer's geochronological measurements of the annual striæ in post Tertiary deposits of similar origin. (Moved by Prof. de Geer.)

III. In favor of establishing a system of continuous synoptic observations of the internal movements in the sea round the coasts of Scandinavia compared with simultaneous meteorological phenomena and fishery statistics. (Moved by Dr. Hans Pettersson (Sweden) and others.) [See Dr. Pettersson's paper on this subject on pp. 100–105 of this REVIEW.]

IV. In favor of the establishing of aerological observations in different parts of Scandinavia. (Moved by Prof. Hesselberg, Christiania.)

V. Emphasizing the need for cooperation between the geophysicists of the Scandinavian countries, both with regard to laboratory and field research, which proposal the Governments of these countries are requested to facilitate as much as possible.

VI. In favor of the project drafted by O. Pettersson that a first-class scientific institute shall be established in Gothenburg for oceanography, marine meteorology, and aerology with the object of studying the dynamics of the movements occurring in the atmosphere and the sea, which determine the climate and the weather of the Scandinavian countries, and of studying the influence of these factors on agriculture, fisheries, navigation, and aeronautics. (Moved by O. Pettersson and seconded by 10 representatives for Denmark, Sweden, and Norway.

WEATHER FORECASTING.

By Prof. V. BJERKNES.

[Address delivered at the meeting of Scandinavian geophysicists at Gothenburg, Aug. 28, 1918.]

It is possible that more than one solution may be found to the problem of satisfactory and practical weather forecasting. It is also possible that among these we may be able to find methods which obviate the necessity of a complete understanding of the phenomenon whose development we are to forecast. Personally, I have no interest in such methods. I am interested in only that method which is based upon a full understanding of the phenomena involved.

Even if this method is difficult, we have at any rate a safe guide. The leading idea is the following: All atmospheric processes obey the laws of physics, first of all those of mechanics and thermodynamics. We are, therefore, really in possession of all the theoretical knowledge necessary to determine future weather. It resides in the equations of mechanics and thermodynamics, or more generally expressed, in the equations of physics. These contain the answer to all questions about the future weather, if only the observations can give us the concrete data with which we are to deal.* The problem of determining the future weather may therefore be reduced to the solution of two special problems:

1. The practical, the obtaining of the necessary concrete data through observation.

2. The theoretical, the evolving of the methods whereby the knowledge contained in the equations can be applied to the observations.

If we state the problem in its most precise form, as a mathematical problem, we can not hope to solve it in the near future. But if we put it into a more practical form, we will then see that the line of progress lies in the continuation of the methods which the meteorologists followed when they began the study of atmospheric processes by drawing synoptical maps, from which they found the baric wind law [Buys Ballot's law], etc. We therefore need not doubt that in this way we will arrive at results which will give us a better understanding, and which will thus react upon meteorological practice.

To a certain extent this has already been confirmed. But the idea of engaging myself in meteorological practice was unthought of, even a few months ago. When, however, the critical time came, when duty demanded

*The effects due to discontinuities in the amount of the atmosphere due to evaporation and condensation are necessarily included.—W. J. H.

our best service in the aid of agriculture, I doubted my right to hold back any longer. From the point of view of my theoretical work it was not yet feasible to take such a step; and the conditions of the start were as unfavorable as possible. It concerned the weather forecasts in the west of Norway, where even in time of peace we had not yet tried the problem, and where now in time of war there is lacking even that which, judging from all our meteorological experience, ought to be the most important, namely weather telegrams from the west—from the the British Isles, the Faroe Isles, and Iceland.

That which gave me hope, however, was some of our newest results. When we wish to proceed rigorously in the theoretical way an unavoidable demand is that we take into account all the variables upon which the solution of the problem is based. A variable which can no longer be kept in the background as before is the wind. Among meteorologists it has not yet reached a synoptical representation. This representation is now given by maps of the lines of flow and of the strength of the wind.[1] These maps present a series of interesting peculiarities, which had to be discussed. Very conspicuous were what we now call the lines of convergence and of divergence, i. e., lines *to which the wind blows in* from both sides, or lines *from which the wind blows out* on both sides. They had been found already on the first maps of this kind, which were drawn at Stockholm at the beginning of this century by J. W. Sandström, who was my assistant at that time. Since then they have been increasingly the object of our attention, particularly of late, after one of my collaborators had succeeded in deducing the law of their propagation as a consequence of the general law of the formation of vortices.[2] In a qualitative form the law reads simply: A line of convergence will always move to the right, a line of divergence always to the left, of an observer who looks along the line in the direction of the wind. Further, the velocity of propagation may, for the main term, be determined by measuring the "divergence" and the "curl" in the nearest surroundings of the lines.

To test these results, observations from a very close net of stations had to be prepared. Observations were therefore gathered from the second and third class climatological stations in the Scandinavian countries, from the light-keepers' journals, etc. The maps confirmed the law with as great an accuracy as it was possible to obtain, though not sufficient for a sharp quanitative test. But, on the other hand, they showed with full sharpness an important empiric law, viz, there belong to every cyclone which is not stationary but in motion two characteristic lines of convergence. (See figure 1*). They both come in from the right side of the path of the cyclone. The one runs almost normal. But the other one always clings nearer to the path of the cyclone the nearer it comes to the cyclonic center, and in the center itself it seems to have the same line as the path. If we, therefore, have a sufficient number of observations to be able to draw this line right into the center of the cyclone, then it will show us the momentary direction of propagation of the cyclone. For this reason we may call it the cyclone's *steering line*. At the same time it ought to be possible on a sufficiently accurate map, by simple measurements near the one or the other of the two lines, to decide at what speed the cyclone is proceeding in the direction which is thus found.

The importance of the two lines of convergence will be still more conspicuous when we look upon their thermal properties. It has been found that the warm air, which is carried to the cyclone and imparts the energy* flows in the sector between the two lines. Under the propagation of the cyclonic system, the steering line will therefore mark the front of a warm wave, and the other line of convergence the front of a cold wave.

This involves also very important meteorological properties. The cold wave, which is, as a rule, marked out sharper than the warm, is followed by violent rain. This falls from the warm air which is raised by the advancing cold wedge of air. It often appears as thundershowers with violent gusts of wind, and in reality this line of convergence is identical with that squall line which we have long known as a frequent follower of cyclones. Also the steering line is associated with rain, at any rate, sufficiently near the cyclone center. But this rain is not in the form of violent showers. It comes not only after the line but also up to 200 km. or more before the line. This

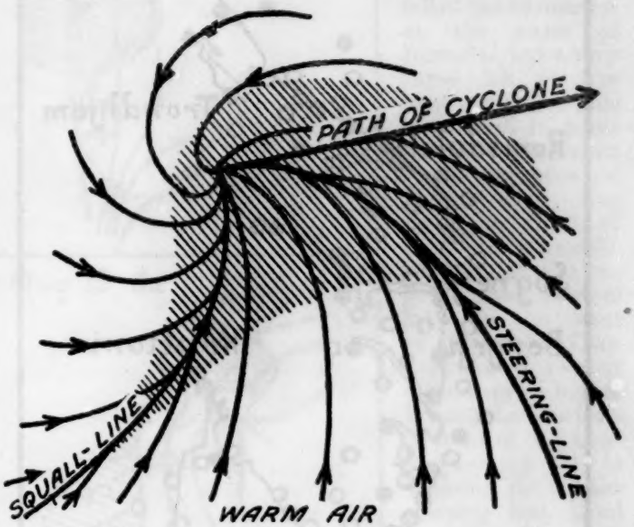

FIG. 1. Cyclone.

rain before the line comes from the warm air which glides up along that inclined plane which borders the underlying cold wedge of air, which is swept away during the forward movement of the cyclonic system.

Evidently we are here at the beginning of a cyclone theory which may be based on real knowledge of the phenomena.

But it is a practical view of the matter that interests us to-day. It is perfectly evident that these results will prove useful for weather forecasting within an extended area, where we get the entire cyclone with both its antennas on the map. But we are not able to try this free application on maps which have normal extension until after the war. It now concerns the application on a small scale, to western Norway, whose weather chiefly is governed by cyclones which pass outside the territory covered by our observations. The question is, have we not, in the identification of the passing cyclones' con-

[1] Cf. V. Bjerknes: Dynamic Meteorology and Hydrography, Vol. II, Kinematic, Washington, 1913.

[2] J. Bjerknes: Ueber die Fortbewegung des Konvergenz- und Divergenzlinien. Meteorologische Zeitschrift, 1917, p. 345.

*Cf. Shaw, Manual, pt. IV, p. 108, etc.—W. J. H.

*Not all of it.—*Ed.*

vergence lines, a new important means of supporting the forecasts under the present difficult conditions?

To serve the preliminary investigations hereof, we got weather reports from the signal stations of the navy district of Bergen. The results proved encouraging, and we went on. The Government granted the necessary means, and by and by the net of stations as shown on figure 2 was erected. It is seen to be a considerably closer net than any hitherto used for weather-forecasting. This is essential if we are to be able to discover and identify the lines of convergence with full accuracy. And it is a step toward the fulfilment of the theoretical demand, that a continuous image of the state of the atmosphere should form the base. An important feature is the double series of barometer stations, one on the islands farthest out to sea, and one at the heads of the fjords. Between them we have a great number of other

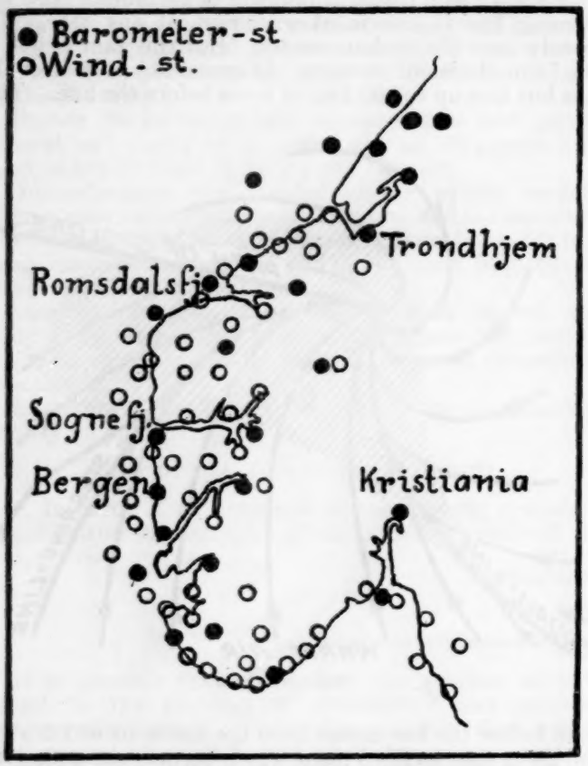

FIG. 2.—Meteorological stations.

stations observing wind and weather without the use of instruments. On the outer islands the direction of the wind is taken very exactly by azimuth dials.

As the stations can never be too numerous, our observers are instructed to give as complete information as possible, not only of the state of the atmosphere at the place itself, but even in its surroundings. Our common instruments, barometer, thermometer, etc., can only give the measured quantities in one single point. But observations of what we call weather, permit more complete communications. Our observers have accordingly been instructed to report not only rain at the place, but even rain falling within sight, and the region of the sky where it is seen. Further, they specify the cover of clouds, not only in accordance with the common climatological rules, but add also the region of the sky where the clouds or the different forms of cloud appear. If the whole sky is completely covered, except for a narrow clear stripe on the horizon, the direction where this clear line is seen is reported. In case of a completely free horizon the cirrus clouds are seen at a distance of more than three hundred kilometers, and lower clouds at correspondingly shorter, but still at considerable distances. It is therefore quite possible to arrange a set of stations which will be able to give complete reports of the appearance of the sky over the whole region of observations.

These data concerning the appearance of the sky are of special importance from the stations at the edge of the sea. Here the observations have to be extended as far as possible into the inaccessible regions. But then the question is: What is to be looked for farthest away on the horizon? If the sky is covered at the station, it is evident that if a clear stripe is seen far away on the sea margin the report of this clear stripe will be most important. But we are more puzzled as to what should be reported on clear days. In order to get hints, I have visited most of our coast stations and talked with the people. It is well known that in many cases fishermen and seamen can predict coming weather with great accuracy. I have asked them concerning the signs which they use. It is not easy to come to the bottom of the matter. Evidently a complex of small signs is intermixed with much superstition. But now and then some safe hints have been received.

When a storm is brewing, a dark stripe is generally seen on the horizon. A pilot at Lindesnäs gave me the characteristic information that when this dark stripe approached from southwest, the rain would come with a southeast wind. After this, I could no more be in doubt concerning the character of the stripe. It must be formed by high clouds marking either the cyclone itself or one of its lines of convergence. These will, when they approach from southwest, give wind from southeast as soon as they have arrived. These results having been obtained, a number of coast stations were instructed to report "brewing up" when these signs were seen. The reports proved useful and should soon lead to further progress.

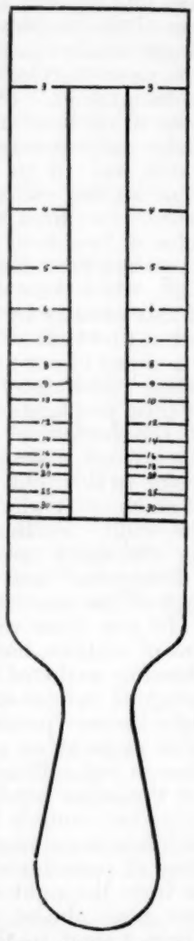

FIG. 3.—Distance measurer.

Naturally we must proceed carefully. Our observers have no scientific education, and, ignorant of the aspect of the phenomenon, we do not know which observations are worth while. As, however, on a later occasion, I heard the watchman at one of our stations state simply in degrees the height which the edge of the stripe might have been above the horizon, the next step was given. If the edge of the stripe is sharp enough to be spoken of in this way, it must be possible to determine the distance of the storm. We know that the cirrus clouds, which, seen from the side, form the stripe, have a height of about 10,000 meters above sea level. Their distance from the observer will then be obtained from their apparent height above the horizon. The result was

the construction of the distance measurer shown in figure 3. It is to be kept 50 centimeters from the eye, so that the lowest divisional line is seen against the horizon. The figure at the divisional line coinciding with the edge of the stripe will then give the distance of the storm. If from time to time we take the azimuth of the bank of clouds, and determine the distance, it must be possible to determine approximately the course of the storm, and also if it will reach a given place, and when.

The instrument is now being distributed among the coast stations, and reports on the situation of banks of storm clouds have already often proved useful. On the other hand, more complete reports, which might give the course and speed of the storm, have not yet been received.

But no matter how far we can look in this way into inaccessible regions, forecasts for an outpost district such as the west coast of Norway will remain precarious. The equation will determine the future state at any time, in every point of the atmosphere, only on condition that in addition to the exterior conditions, we know the initial state of the entire atmosphere. And the more limited is the region for which the initial state is known, the more limited will also be not only the district for which rational forecasts can be made, but even the period in which they will remain valid. A cyclone situated so far off that its bank of clouds can not be observed can very well reach the coast in 6 to 8 hours. This entails an important restriction: The forecasts can be issued for a very limited period only. We have chosen the shortest period which can still be of use: Based upon the observations made at 8 o'clock in the morning, forecasts are issued for the rest of the day, and even this will in some cases be beyond permissible limits.

I shall give a few examples of charts of lines of flow, which, in connection with the corresponding charts of pressure, temperature, tendency of barometer, etc., have been used for the forecasts.

A very instructive case occurred on August 14 and 15, in the morning. On the morning of the 14th rain was reported from the west coast north of Bergen. At the same time was reported a "brewing up" 180 km. west of a station on the Romsdal coast. This observation proved a considerable extension of the district of rain to the north on the sea. The barometer was falling rapidly on the west coast, more slowly at the coast of Romsdal. This seemed to indicate a cyclone taking the course southward along the coast. The circumstance that neither of the two lines of convergence could be identified seemed to point in the same direction, as lines of this kind are not to be found on the left side of the path of a cyclonic track.

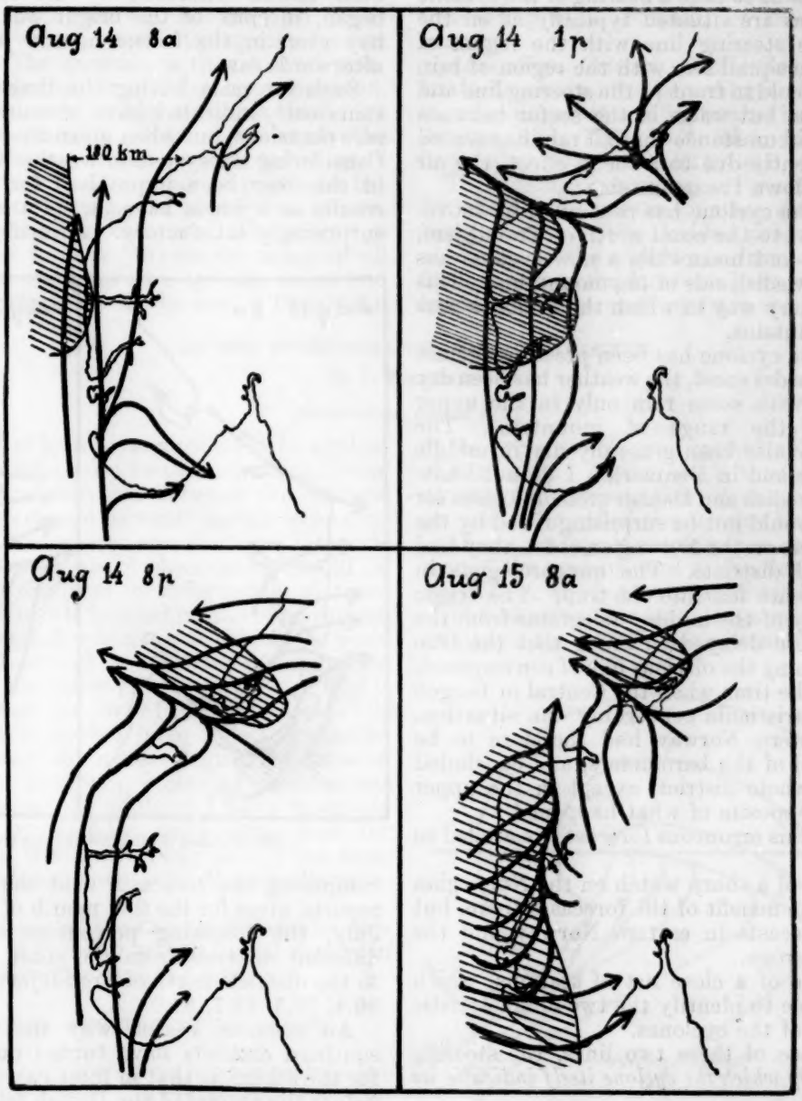

FIG. 4.—Lines of wind flow and rain areas, Aug. 14-15, 1918.

The midday charts for the same day, fig. 4, show a slow fall of the barometer at the coast of Romsdal, but a very rapid fall on the west coast. This seems still to point toward a movement of the low pressure southward. But now the chart of wind shows a marked line of convergence that reaches land on the coast of Romsdal. Temperature is two or three degrees higher behind this line than in front of it. Consequently it is without doubt the steering line. And to judge from the situation of this line the cyclone should go toward the east, not toward the south. Thus the signs seem to be contradictory, and the question is which of the two signs are we to believe.

The evening chart shows that the steering line has moved considerably toward the east. At the same time its character as a steering line is further marked by rain from the inclined plane in front of it. Meanwhile the fall of the barometer has again been more rapid on the west coast than on the Romsdal coast. The barograph at Bergen shows a very sharp fall. This seems to indicate that the cyclone will take the course toward the south. Are we now to place our confidence in the fall of the barometer or are we to think that the cyclone will follow its steering line?

The morning chart for the next day gives the answer: The steering line has continued its propagation undisturbed toward the east, and now it has been followed by a squall line also, which has reached the west coast. The strange fall of the barometer on the stations of this coast has been the consequence of the propagation of this line toward the east, not of any propagation of the cyclone toward the south. As soon as the line had passed, the barometer also ceased to fall on the west coast but the fall continued on the Romsdal coast. The two lines of convergence now allow us to take a bearing of the cyclone on the sea. The lines are situated typically as on the schematic figure, the steering line with the region of rain in front of it, the squall line with the region of rain behind it. The air is cold in front of the steering line and behind the squall line, but warm in the sector between the two lines. The circumstance that all rain has ceased in this sector is evidently due to a foehn effect, the air current here coming down the mountains.

On the next day the cyclone has continued its movement towards the east to the coast north of Trondhjem. Here it has subsided and meanwhile a new cyclone has been formed on the Swedish side of the mountains. This seems to be the ordinary way in which the cyclones pass across a chain of mountains.

During the time the cyclone has been pressing against the west and the Romsdal coast, the weather has been dry in eastern Norway, with some rain only in the upper valleys underneath the range of mountains. The weather has probably also been generally dry in middle and southern Sweden and in Denmark. I do not know the forecasts of the Swedish and Danish meteorologists for these days. But it would not be surprising if led by the tendency of barometers on the Norwegian coast, they had predicted rain in all districts. The meteorologists in Christiania at all events fell into the trap. The tragic reason was that many of the midday telegrams from the coast of Romsdal were delayed so much that the true chart of wind, containing the obvious line of convergence, did not yet exist at the time when the Central in Bergen sent its report to Christiania concerning the situation. The forecast for eastern Norway had therefore to be founded upon the fall of the barometers, and concluded with rain over the whole district, except in the upper valleys, exactly the opposite of what happened.

Not least through this erroneous forecast, we are led to strongly accentuate:

I. The importance of a sharp watch on the Norwegian coast, not only for the benefit of the forecasts there, but as much for the forecasts in eastern Norway and the whole of northern Europe.

II. The importance of a close net of stations, which alone makes it possible to identify the two characteristic lines of convergence of the cyclones.

III. The importance of these two lines, the steering line and squall line, *by which the cyclone itself indicates its course.*

The experience of this summer has more than sufficiently shown us to what high degree our weather is controlled by the lines of convergence, which sweep over the country during the passing of the cyclones. I will supplement the preceding example with a simpler one.

On the morning of July 18 rain was reported from the southwest coast and a falling barometer on both sides of the southern point of the country. The chart of wind, figure 5, shows that a line of convergence has landed, and the fall of temperature characterized this as a squall line. The steering line could then point only to the north, parallel to the coast, and the unknown cyclone then had to move this way. The forecast was given with the empiric knowledge of the velocity of propagation of the squall line: More rain for the southern districts, rain soon for the next northern districts, rain after midday in the districts north of Sognefjord. The chart for 1 p. m. shows that the rain had reached the mouth of this fjord, and it continued northward during the afternoon. Later on I happened to visit a place where either this or another forecast of the same character had been useful. Alarmed by the forecast, the peasants began, in spite of the bright weather, to fetch in the hay even in the forenoon, and just in time, as they afterwards saw.

Such forecasts having the time of the occurrence of rain clearly indicated, have, of course, been issued only on rare occasions, but when given they have been successful. Considering the system of weather forecasting, which has in this way been improvised for western Norway, its results as a whole have, in spite of all difficulties, been surprisingly satisfactory. A verification, worked out by

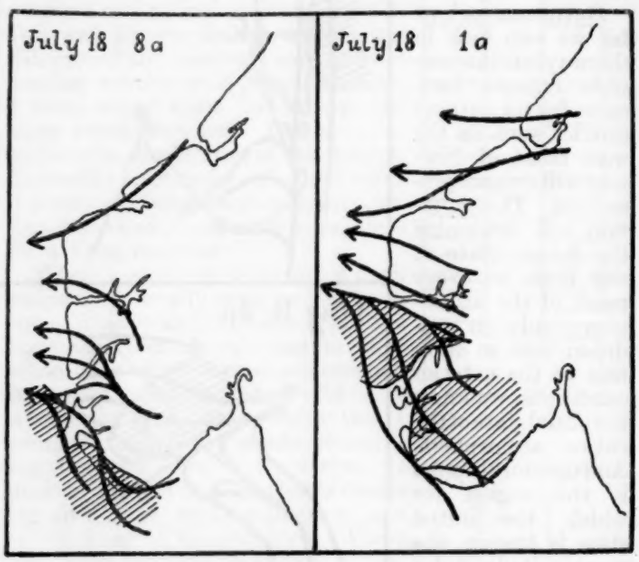

FIG. 5.—Lines of wind flow and rain areas on July 18, 1918.

comparing the forecasts with the midday and evening reports, gives for the first month of the forecasts, namely, July, the following percentage of hits for the eight different districts from the south point of the country to the districts north of Trondhjem: 81.3, 79.2, 77.1, 93.6, 86.4, 79.5, 88.7, 84.0.

An essential reason why the results for the three southern districts have turned out less favorable than for the others, is that in most cases they had to be issued before the arrival of the Danish telegrams. The average per cent of hits is 83.7. Although the results thus have proved satisfactory, owing to the war we must work for the present, as it were, with blinded eyes; nevertheless, we have every reason to expect that in the future the area from which the observations are obtained will be restored to its former extent.

The system, however, has certain failings which can not be remedied even by this extension. The smaller the cyclones the more difficult it is to make forecasts of them. Diminutive cyclones are very frequent. Formerly they slipped undiscovered through the wide

meshes of the old net of observations. With our close net of stations we can, to a certain extent, follow and forecast them, and the closer becomes the network the farther we can advance. But at last the limit of what is obtainable is reached. We can not make it close enough to predict every local rain shower. There is, however, one way open by which the system can be completed, and this way I hope will be tried by next summer.

A similar view of the sky, only still more extensive than from the coast, can be obtained from favorably situated mountains. Everyone who has traveled in the mountains knows that we can see wandering rain showers at a great distance. The question is then to find practical methods by which their tracks can be determined, just as the course of distant banks of storm clouds are found from the coast stations. Now, if we study the view from the top of a mountain by the use of good charts, we can identify a great number of points on the ground, such as summits, ridges of mountains, rivers, lakes, towns, villages, and churches, etc. The chart can be especially prepared for the purpose by marking all the characteristic lines and points we are able to see and hatching the regions, which can not be seen. Then when the showers of rain advance the observer will be able to draw on the chart the part of the front line of the shower which is turned to him. By drawing this line from hour to hour he will see how the shower develops and propagates, which districts are being threatened, and when the rain will reach them. The observer will then not only be able to give valuable information to the central offices but he can also send forecasts direct to the threatened districts. From a comparatively small number of mountain stations, which cooperate and supplement each other, it must, in this way, be possible to organize a system of forecasting local showers for the greater part of the country.

Addendum, October, 1918.—For the same eight districts as above, the percentage of verifications for the months of August and September have been the following: August, 85.1, 77.7, 83.3, 79.5, 85.1, 92.4, 90.7, 96.3; September 94.0, 94.0, 92.0, 96.0, 90.0, 94.0, 88.0, 88.0.

The average percentage of verification has thus been for the three summer months: July 83.7, August 86.3, September 92. The decided progress at the end is due above all to the experience from August 14 and 15, as from this date the forecasts have, in dubious cases, been based with increased confidence upon the steering line.

ON THE STRUCTURE OF MOVING CYCLONES.

By J. BJERKNES.

[Dated: Bergen, October, 1918.]

When the equations of hydrodynamics are to be applied directly to concrete atmospheric motions, two conditions should be fulfilled: The distances between the stations giving the observations should be small enough to be considered as differentials of space, and the time intervals between the successive periods of observation should be small enough to be considered as differentials of time. Neither of these conditions is fulfilled by the observations available from daily weather maps and printed in yearbooks. Distances amounting to hundreds of kilometers and time intervals of six hours are too great.

In order to get at least the first of these conditions fulfilled, to some degree at least, I have collected detailed data from the archives of the meteorological institutes in Norway, Sweden, and Denmark, including observations from third-class stations. In addition I have examined the comparatively very detailed daily maps used for weather forecasting in western Norway during the summer of 1918, and combined them with the simultaneous study of the sky.

In this way I have been led to some general results concerning the structure of cyclones, which I shall outline in this paper, and shall consider in detail later.

THE STEERING LINE AND THE SQUALL LINE.

The lines of flow in a cyclone have approximately the character of logarithmic spirals. By increasing the number of observations, however, several deviations from the regular spiral shape appear. Among a multitude of details, certain characteristic traits seem to recur more or less markedly in all cyclones yet examined.

Every cyclone that is not stationary has two lines of convergence, which are greater and more conspicuous than any others, and are distinguished by characteristic thermal properties, as shown in figure 1.

The first of these lines comes in to the center from the front of the cyclone, lying in its entire extent on the right side of its path. The tangent to the line at its terminus in the cyclonic center seems to be identical with the path of the latter. As the line is thus giving the momentary direction of propagation of the cyclone, it may, with propriety, be called the *steering line*.

The other line of convergence comes in from the right rear of the cyclone, and is identical with the well-known *squall line*, which accompanies cyclones.

The steering line and the squall line are intimately related to the distribution of temperature, as they border

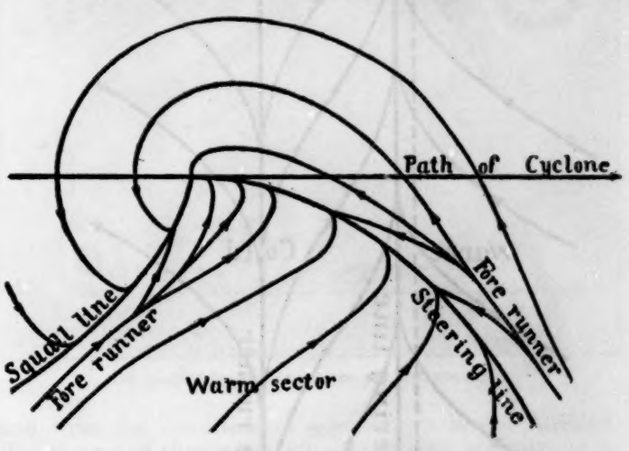

FIG. 1.—Lines of flow in a moving cyclone.

the warm area of the cyclone, or, as we may call it, its "warm sector."

Both the steering line and the squall line move according to the law of propagation for lines of convergence,[1] viz, in the northern hemisphere toward the right, relatively to the direction of the wind along the

[1] J. Bjerknes: "Über die Fortbewegung der Konvergenz- und Divergenzlinien." Meteorologische Zeitschrift 1917, 10/11.

line. The passage of the steering line, having warm air to the left, will therefore cause an increase of temperature, and the passage of the squall line, having cold air to the left, will accordingly give a decrease of temperature. These thermal effects correspond to the well-known increase of temperature in front of cyclones and the decrease behind them. The discontinuous character of the change of temperature is peculiarly striking during the passage of the squall line, but the change due to the passage of the steering line is also easily perceptible.

THE STEERING SURFACE.

The air masses flowing in from both sides toward the steering line will not mix. Up to great heights there will exist a distinct boundary surface, which separates them. This boundary surface, cutting the earth's surface along the steering line, may for convenience be called the steering surface. This surface leans toward the cold side, the cold air thus forming a flat wedge under the warm. Figure 2*b* shows the horizontal field of flow in the near vicinity of a steering surface, and figure 2*a* gives a representation of the motion in vertical projection.

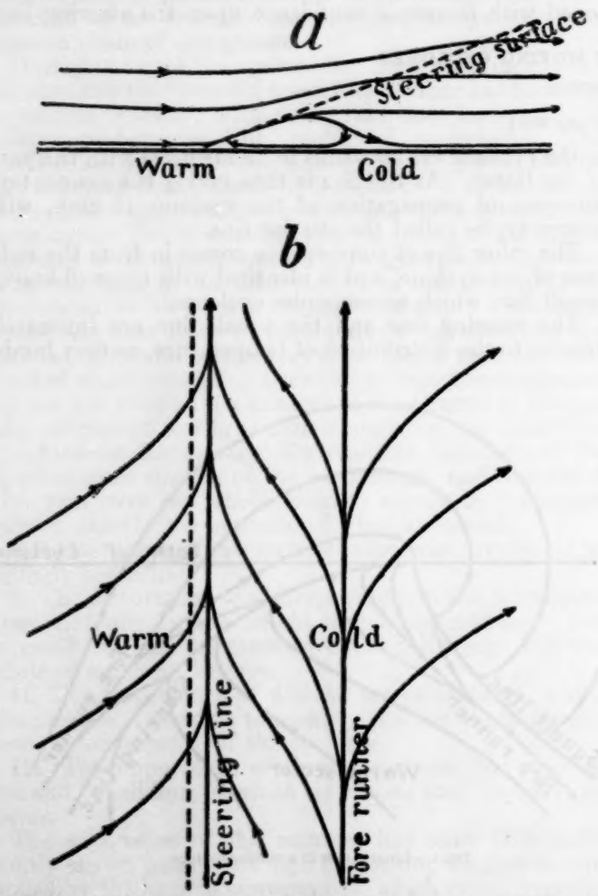

FIG. 2.—Moving steering line.

The warm air flowing in from the left ascends the steering surface, sweeping with it the nearest layer of underlying cold air. This cold air, however, can follow only to a certain height. It soon drops down again, and on the place where it reaches the ground a line of divergence will appear in the field of horizontal flow (fig. 2*b*).

Every moving steering line is thus preceded by a line of divergence, which is very often seen on the detailed maps at a distance of about 50 kilometers. The air between this forerunner and the steering line itself has a rolling motion. The air to the right of this rolling mass moves off horizontally, having a velocity component in

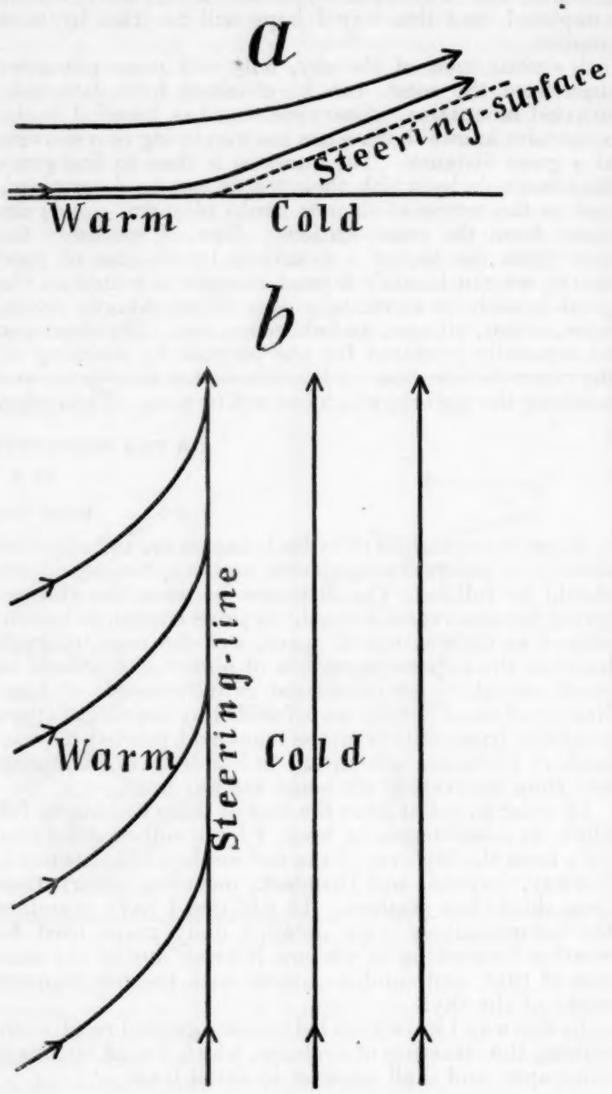

FIG. 3.—Stationary steering line.

a direction normal to the steering line, corresponding to the velocity of propagation of the system.

It should be noticed that the line of divergence preceding the steering line as a forerunner has a forced propagation in a direction opposite to that generally found for such lines. The term due to the rotation of the earth, under ordinary circumstances predominating, is apparently overcompensated by frictional terms generally neglected.

It will be useful also to refer to figure 3, representing the motion found at stationary steering lines, having no forerunner. Should this steering line be propagated toward the right, the entire cold mass must ascend to give place for the warm. The existence of the forerunning

line of divergence seems thus to be a necessary condition for the propagation of the steering line.

THE SQUALL LINE.

The air masses flowing from both sides toward the squall line will remain separated by a boundary surface that for convenience may be called the squall surface. This surface does not, like the steering surface, simply resemble an inclined plane. As shown by W. Schmidt's investigations [2] it is fronted by a "head," at the back of which it has, as far as we know, an almost horizontal course, interrupted only by some small waves. Data concerning its continuation to greater heights are not yet at hand.

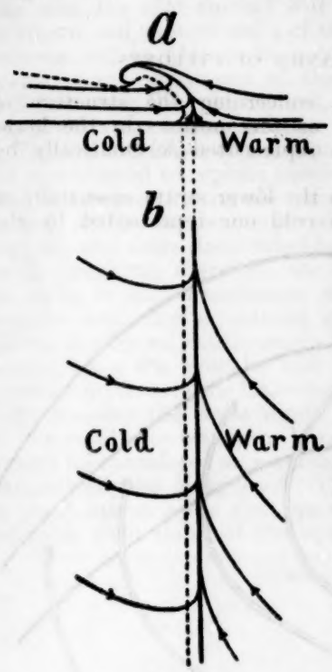

FIG. 4.—Squall line.

Figure 4*b* shows the horizontal field of flow in the immediate vicinity of the squall surface, and figure 4*a* gives a vertical projection of the same motion. The squall surface itself is represented by the broken line on both figures. The cold air flowing in from the left displaces the warm air in front of it. The warm air is forced to ascend rapidly the abrupt front of the head, and afterwards to perform only occasional ascensions and descensions.

At the center of the cyclone, the steering and the squall surfaces join into one. The entire surface, cutting the ground along the steering and squall lines, forms a wide flat valley, conveying the warm air current upward over the underlying cold air.

THE DISTRIBUTION OF VERTICAL MOTION, AND OF CLOUDINESS AND PRECIPITATION.

When the field of horizontal motion is known through the wind observations from meteorological stations, the vertical motion in lower strata may be constructed by the aid of the equation of continuity. Such constructions have made apparent characteristic distributions of vertical motion. The following practical, although not exact rule, has in this way been obtained for cyclones: The areas of small deflection of the wind from the gradient are generally areas of fast upward movement; and vice versa. The areas of great deflection are generally areas of slow upward or even of downward movement.

The smallest deflections are found on the right front of cyclones, viz: in the warm sector. Accordingly the ascending motion starts at the ground in the warm sector, and has its greatest values along the two lines of convergence bordering it. Outside the warm sector, only slow upward movements are found, and on the rear of the cyclone even descending movements occur.

In fig. 5, the distribution of cloudiness and precipitation over the cyclone area is outlined. As all ascending motion of importance originates from the ground in the warm sector, cloudiness and precipitation pre-eminently are involved there. The warm air spreads, however, over greater areas in the higher strata than at the ground, the surface of separation leaning from the warm sector outwards over the adjacent cold areas. Therefore the effect of ascending warm air may also be observed from the surrounding districts, which are cold at the earth's surface.

A surface of discontinuity at which there is a sudden change of temperature and of wind velocity may, according to a formula of Margules,[3] have an inclination of equilibrium, depending upon the difference of temperature and the difference of velocity. In the case which we are considering, the surface of discontinuity is moving,

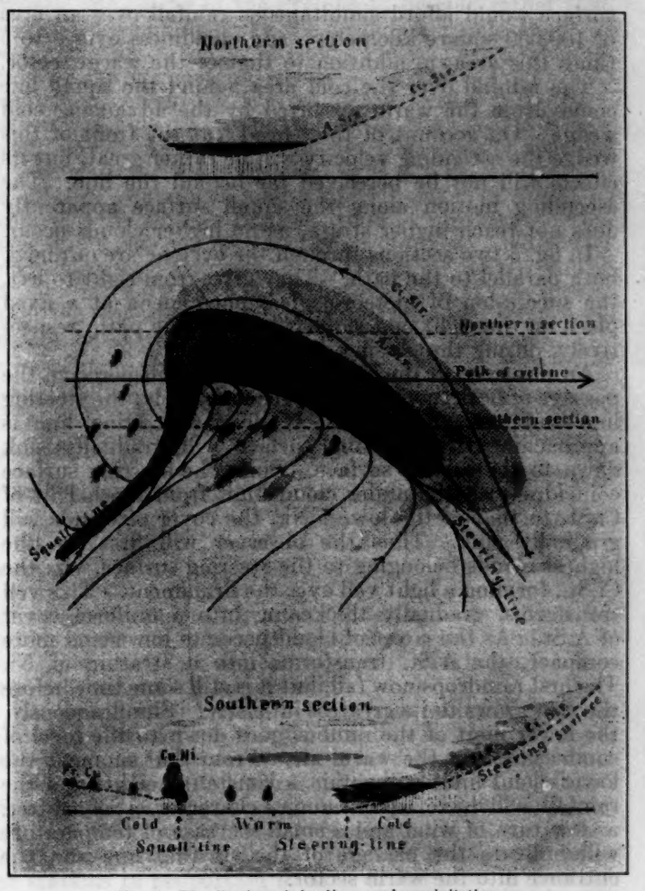

FIG. 5.—Distribution of cloudiness and precipitation.

and thus the condition of equilibrium is not fulfilled. But in case of slowly moving systems we are entitled to consider the deviations from the equilibrium as small and reckon approximately with the equilibrium values.

The formula of Margules, when applied directly to steering surfaces found on detailed maps, has led to values of its angle of inclination amounting to a fraction of a degree. To get an idea of how far precipitation and cloud areas, caused by the ascension of warm air, will extend

[2] W. Schmidt: Wien. Sitzungsberichte I. 119, IIa, 1910, p. 1101. Meteorologische Zeitschrift 1911, p. 357.

[3] Margules: "Energie der Sturme" Jahrbuch der K. K. Zentr. Anst. fur Meterologie 1903 Anhang. English in the Mechanics of the earth's atmosphere, a collection of translations by Cleveland Abbe. Smithsonian Miscellaneous Collections, Vol. 51.

beyond the steering line, we may calculate with an average inclination of 1:100. Lower nimbi, at the height of 500 meters, will then extend 50 kilometers beyond the steering line, and the intense rain will fall to this distance. Higher nimbi, up to 2,000 meters, may bring weaker rain 200 kilometers in front of the steering line, and single raindrops may occur at a still greater distance. Outside the district of rain clouds, the higher clouds, alto-stratus and cirro-stratus, will extend. If we suppose the same inclination up to the highest strata, the Ci.St. would appear 800 kilometers ahead of the steering line.

Cloudiness and precipitation in front of the cyclone, extending not only over the warm, but also over great cold areas, may thus be sufficiently explained by the ascension and spreading out of warm air along the great surface of separation. If the steering line in the before mentioned numerical example had a length of 500 kilometers, the ascension along the corresponding steering surface would afford simultaneous rainfall over an area of 100,000 square kilometers, and cloudiness over 4 to 5 times this area, in addition to that of the warm sector.

The rainfall over the cold area behind the squall line comes from the warm air lifted by the advancing cold wedge. On account of the "head" at the front of this wedge the ascending velocity will be rather great, but its effects will not be perceived far behind the line. The ascending motion along the squall surface apparently does not reach higher strata, as no higher clouds occur.

In fig. 5 two sections through the cyclone are outlined, both parallel to the path. They give, from right to left, the succession of meteorological phenomena at a fixed place on the right and the left sides of the path, respectively, during the passing of the cyclone.

An observer to the right of the path will perceive the passage of both lines of convergence, namely, the steering line and the squall line. While the steering line is approaching, the steering surface will gradually sink down to the earth's surface. Since the steering surface coincides with the under cloud limit from the height of Ci.St. to that of the lowest Ni., the cover of clouds will gradually sink. Thus the observer will first see the highest clouds belonging to the steering surface, viz: the Ci.St., forming a light veil over the firmament. This veil transforms, gradually thickening into a uniform cover of A.St. As the cover of cloud becomes lower and more compact, the A.St. transforms into a stratum of Ni. The first raindrops now fall, but it is still some time before the rain grows to its greatest intensity. Simultaneously, the lower limit of the nimbus goes down to the level of condensation in the warm air. From that moment the lower cloud limit will retain a constant height, and the rainfall will have a continuous character. Soon after, a slow turn of wind and a small increase of temperature will indicate the passage of the steering line and the entrance into the warm sector.

In the warm sector no striking changes will occur until the squall line is approaching. Then the wind suddenly turns to the right, simultaneously increasing to violent force; the temperature falls rapidly; the nimbus transforms into Cu.Ni., and the rain pours down in heavy squalls. The heavy rainfall does not last long. Soon after the passage of the squall line, a clear blue sky appears, all higher clouds having already disappeared. The clearing of the sky is only interrupted by smaller showers.

An observer to the left of the path will be passed by neither the steering line nor by the squall line. He will, however, observe the phenomena due to the ascending motion up through the valley formed by the joined steering and squall surfaces. Thus he will see the veil of Ci.St. gradually thickening down to A.St. and Ni. The nimbus, however, will not go as low down as in the warm sector, and the rainfall will not increase to the same intensity. The clearing of the sky takes place later without any striking changes of wind, temperature, or form of cloud.

The cold air in cyclones performs a part like that of a high continent against which a warm wind is blowing. Above the level of condensation of the ascending air the "continent" will be covered by "fog." This "fog," which may be observed from below through the transparent continent of cold air, is according to the height, called Ni., A.St. or Ci.St.

ON THE MECHANICS OF CYCLONES.

The preceding results concerning the structure of cyclones may, in so far as the motions in the lower strata are concerned, be represented schematically by figure 6.

The cyclone consists in the lower strata essentially of two opposite currents, a cold one represented by the

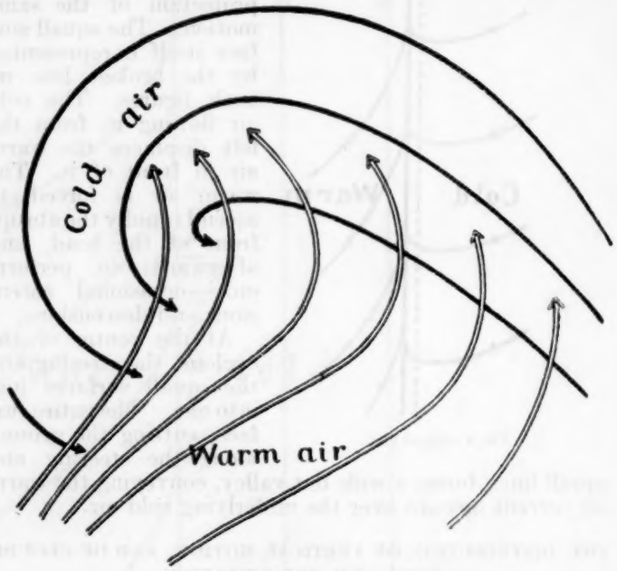

FIG. 6.—Cyclonic motion in lower-air strata.

heavy black lines and a warm one represented by the light double lines. As a combined effect of the barometric depression and the deflecting force of the earth's rotation both currents are turned about the cyclonic center. As the combined effect of this turning motion and their different specific weights, the cold current is screwed underneath the warm one, and the warm current screwed up above the cold one. This combined motion propagates along the steering surface, not unlike a wave motion, the kinetic energy being furnished by the potential energy of the system of warm and cold air, lying beside each other on either side of the steering surface. The cyclonic motion effects the transformation into a state with reduced potential energy, involving a reduced angle of inclination, or even a complete disturbance of the surface of discontinuity.

This view leads to a natural explanation of well-known facts. Cyclones are most frequent, and developed to greatest intensity, in the zones and during the seasons of great horizontal temperature gradients, the surface of

discontinuity pre-eminently evolving under such conditions. Further, a series of cyclones often follows approximately the same path, the surface of discontinuity having been only partly destroyed by the first cyclone, so that it may, after a short period of restoration, serve as a steering surface for the next one.

In the case of a stationary steering surface the path of the center would follow the fixed steering line. But as the steering surface is generally already in motion, we can only assert that the momentary direction of propagation of the center is given by the tangent of the steering line at this center.

Taking the general case of a cyclone propagating to the east, the cold current will cover the ground on the northern and western sides of the center, while the warm current will be able to keep to the ground only in the warm sector, southeast of the center. From there it will flow over the cold current, joining the general western drift in the higher strata.

The general effect of the motion described is that cold air is conveyed to regions previously covered with warm, and there spread along the ground; and that in compensation, warm air is conveyed to previously cold air regions, and there distributed in the higher strata. Generally speaking, therefore, the cyclones may be said to be links in the interchange of air between the polar regions and the equatorial zone. This interchange, which is effected continuously in the zone of the trade winds, takes the irregular and intermittent character of cyclonic motions in the latitudes outside the high-pressure belts limiting the trade winds.

The results to which we have arrived may to a great extent be considered as a verification of views developed theoretically by Margules:[4] "The phenomena of motion in great storm areas that we call cyclones are less intelligible than those of the squalls. But these also, at least in middle and higher latitudes, consist of warm and cold masses of air lying adjacent to each other horizontally; cold air often spreads out over the earth in the lower strata behind the passing storm. It is therefore not unlikely that these storms are fed by the potential energy of an initial stage . . . . Otherwise these results verify certain traits in different older theories of cyclones, while they disprove other traits.

We are reminded both of Dove's old theory of the conflict between polar and equatorial currents as well as of the modern "counter current" theory of Milham.[5]* Ferrel's convectional theory is confirmed in its essential part, in as much as the ascending air in the cyclones is warm. This warm air, however, does not form a central core, but comes from the side, covering a warm sector. The general argument against the theory of Ferrel, that statistical investigations have proved a circular area around the center of the cyclone to be cold rather than warm, does not disprove the principal point, that the ascending air is warm, but only the accidental assumption of the symmetrical structure of the cyclone. The confusion concerning this point led to the paradoxical assumtion that the mounting air in the cyclone is cold and heavy. As under conditions theoretically specified by Sandström,[6] a symmetrical cyclone can really act as a kind of centrifugal pump, lifting the cold air of its central core, this assumption contains no intrinsic contradiction, but can now simply be dropped. While thus an unnecessary element of v. Hann's "driven eddy" theory has to be left out, the general view of this theory, that the cyclones are merely partial phases of the general atmospheric circulation, has been fully confirmed.

[4] Ibid.

[5] Meteorology, Milham, New York, 1912, p. 311.

* Milham attributes this to Frank H. Bigelow. See "The mechanism of countercurrents of different temperatures in cyclones and anticyclones." Mo. Wea. Rev., 1903, 31: 72-84.

[6] J. W. Sandström, Ueber die Beziehung zwischen temperatur und Luftbewegung. Met. Zeits., 1902, 19: 161-171.

POSSIBLE IMPROVEMENTS IN WEATHER FORECASTING.

With special reference to the United States.

By V. BJERKNES.

Probably the most important step that can at present be taken for the improvement of the weather forecasting will be the introduction in the daily weather service of good charts representing the lines of wind flow.

The drawing of these charts presents no special difficulties. When a meteorologist has gained sufficient acquaintance with them, he will draw them as easily and as quickly as somewhat complicated isobaric or isothermal charts. My Gothenborg address [1] and J. Bjerknes's paper [2] give useful hints concerning the use of these charts, and their connection with the weather. But accumulated personal experience will also be of great importance.

These charts will, however, have their full prognostic value only when the observations permit them to be drawn in such detail that the two fundamental lines of convergence of the cyclone, steering line, and squal lline, can be accurately identified.

For this purpose it is necessary that the observations of the wind be made and telegraphed as accurately as possible. In this respect there is occasion for an important improvement in the system of observations in the United States. At present only eight directions of wind are reported. Making the observations of the wind directions as accurately as the conditions of each station will permit and telegraphing in detail the results thus obtained will be an important step in making it possible to draw the true lines of flow.

On the other hand, it will be highly desirable to get a closer network of stations. How far it will be necessary or desirable to go in this respect can only be shown by experience.

Besides about 300 telegraphic stations, the United States has a great number of climatological stations, about 3,000 if my memory is correct.* If all the sewere made telegraphic we should get about the same number of stations in proportion to area as are used in western Norway. As desirable as an expansion on this scale would be, considered as an experiment, it would probably meet with difficulties from the point of view of the telegraphic service; and quite likely it will not be necessary. The close network of stations in western Norway is necessary, partly on account of the complicated topography and partly on account of the exceptional difficulties during the war, when practically no weather telegrams from abroad are received. With the simpler topographical conditions in the United States, and the comprehensive view obtained from the great area of observations,

[1] Weather forecasting. This REVIEW, pp. 90-95.

[2] On the structure of moving cyclones. This REVIEW, pp. 95-99.

* About 4,500.—Ed.

it is probable that much could be accomplished by doubling or tripling the number of the stations. It will, however, be of great importance to have a network of stations along the Pacific coast, with a closeness corresponding to that of the west coast of Norway, in order to be able to catch the arrival of lines of convergence, and thus determine as early as possible the direction which the cyclones will take. A close network of stations will probably also be useful on the Gulf coast.

Even if it might be desirable, it would not be necessary to give these new stations the same complete instrumental equipment as the old ones. Their most important task would be to give as accurate reports as possible:

I. On the direction and strength of wind, from which to determine the lines of flow.

II. On the temperature, from which to determine the sudden rise or fall at the lines of convergence.

Concerning further observations which may be desirable, e. g., concerning rain at or within sight of the station, on the appearance of the sky, etc., or concerning special observations which may be had from the coast stations and from favorably situated mountain stations, the reader is referred to my Gothenborg address.[3]

Concerning the advantages which might be obtained by this extension of the weather service it can be stated that if, as in western Norway, the observations in the morning are made the basis of forecasts for the rest of the same day, these forecasts may be given with great confidence and in great detail for the different districts, usually with an indication of the time of the day when the rain will begin.

It will be more difficult to express an opinion as to how forecasts for the following day, or a still longer period, would succeed. For in this field we have had no experience in Norway, where in the present abnormal conditions the duration of the forecast had to be limited to the utmost. But we have every reason to believe that conditions even in this respect will prove favorable on an area of observations of an extent as great as that of the United States.

It is of course very difficult for me to estimate the cost of the indicated change of the weather service in the United States. If, as I believe, a sufficient number of climatological stations already exist, the main expense would be on account of the increased telegraphic service.

It may be instructive to report that the Norwegian Government granted 70,000 kroner ($18,667) for experiment with the weather forecasting this past summer [1918] in western Norway according to the new system.

The main expense was for the telegrams, and the sum turned out to be sufficient for the purpose, even though it concerned a new start rather than an extension of a system already existing. The grant was given principally on the ground that even if there should result an increase of only 1 per cent in the returns from agriculture the expense given for the weather forecasting would be many fold covered.

[3] Pp. 90-95 of this REVIEW.

SYNOPTIC STUDY OF HYDROGRAPHICAL PHENOMENA.

By Dr. HANS PETTERSSON.

[Dated: Göteborgs Högshole, Sweden, Dec. 24, 1918.]

In a previous communication[1] to the MONTHLY WEATHER REVIEW I have set out the reasons for an increased intensity of hydrographical observations in coastal waters and have also described some new technical resources evolved for that purpose.[2]

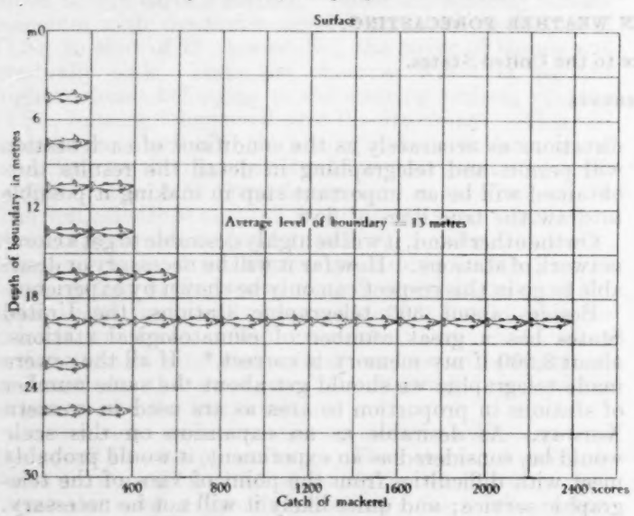

FIG. 1.—Relation of the catch of mackerel to the depth at which dense sea water is found.

Mainly through the daily soundings taken for nearly a decennium at Bornö Station in the Gullmarford, the first example of continuous hydrographical observations on record, the surprising variability of the situation in coastal waters was first proved and investigated. The close connection existing between similar changes and biological phenomena has repeatedly been confirmed by Swedish hydrographers, by G. Ekman and O. Pettersson for the rich catches of herrings made in winter off the west coast of Sweden and by the author for the catch of mackerel in summer. In figure 1 a graphical representation is given of the catches of mackerel made at Bornö during the summers of three years as a function of the simultaneous depth of the 30 per cent boundary in the fiord; nearly 1,000 scores were caught when the boundary was below its average level against less than 1,000 scores when it was above the average.

In winter, when these movements are especially large and rapid, the disappearance from the surface of water of North Sea origin (warm and salt) replaced by a sheet of ice-cold brackish water from the Baltic, or vice versa, will have a marked effect on the local air-temperature, the freezing of the fiords or the breaking up of their ice. The great scientific interest which these internal movements in the sea command is thus further enhanced by their bearings on practical questions.

Now the results from the investigation at Bornö are open to the objection that the displacements of the boundary observed at that place may be a *local* phenomenon limited to the Gullmarfiord—i. e., of the nature of the internal seiches studied in Scotch lochs by Wedderburn.[3] The best method of proving or disproving this suggestion is obviously to make continuous observations at one or more other points on the coast parallel to those at Bornö. A first attempt in this direction was made by the author

[1] MONTHLY WEATHER REVIEW, 1917, p. 159.

[2] The new Amundsen N. polar expedition has been equipped with a set of these instruments, its hydrographer, Dr. Sverdrup, studying their use at my institution before starting.

[3] Proc. R. Soc. Edinb. Vol. 29, p. 98.

in November, 1915. Exceptionally stormy weather which then prevailed prevented the observations from attaining the degree of completeness desired. At three of the points of observation, situated in the open sea, soundings could only be taken every third day, and at the fourth and last point besides Bornö, the lightship *Grisbåden*, soundings were taken once daily. The method employed was the rather cumberson way of titrating water samples collected by the water bottle. However, the results gave fairly good evidence that the larger displacements of the boundary, lasting for several days or more, form a part of a general phenomenon comprising the whole coast of Bohuslän. Besides, hydrographical changes of less amplitude and shorter duration were also apparent.

During two months of last summer a new attempt was made by the author to establish a system of "synoptic" observations at three different points on the coast of Bohuslän, viz, at Bornö, at Hättan, to the north of Marstrand, and at Böttö lighthouse outside Gothenburg. (See fig. 2.) The distance between the second of these places and each of the two others is about 50 kilometers. At all of them "U-tubes" or hydrostatic densimeters[4] were put up, by means of which any change occurring in the average density of a column of water extending from the depth of 1 meter below the surface down to a certain depth, D, can be observed in the simplest way possible. The depth D, which represents where the lower orifice of the hydrostatic system is placed, amounted to 25 meters at Bornö and at Hättan, whereas in the shallow waters round Böttö only 20 meters could be attained.

At the two places last mentioned there is always somebody on duty day and night, so thatt he instruments could be read regularly at intervals of six hours, viz, at 2 a. m. 8 a. m., 2 p. m., and 8 p. m. At Bornö readings were only taken in daytime, from 8 a. m. to 8 p. m. every third hour. To obtain a record of such completeness by means of the older technique would have involved a large amount of qualified labor.

The records from all three places are reproduced in figure 3, where the readings of the U-tubes are plotted against time, a rise in the curves corresponding to an upheaval of the boundary and vice versa. The scale is, of course, arbitrary, but a simple calculation shows that a change in the readings of 1 centimeter should correspond to a vertical displacement of the boundary of about 30 centimeters, or to a variation in the average density of the water column between 1 and 20 meters depth of about 0.0002.

A strong gale in the middle of August disconnected one of the lead tubes at Hättan. The records from Bornö and Böttö are given for a few days longer.

It is seen from the curves that considerable vertical displacements of the boundary have been going on almost without rest the whole time the investigation lasted. The similarity between the curves is very marked, especially between the curves from Börnö and Hättan, practically every large upheaval or subsidence in one of them being also visible in the other. The curve from Böttö, although it has many conformities with the two others, shows in general variations of less magnitude and has a flatter appearance. Especially during the middle of July it is almost devoid of "waves."

To a certain extent this discrepancy may be due to the relatively small value of the depth D, 20 meters at Böttö. Changes in the density between that depth and 25 meters would not affect the U-tube at that place, but would be recorded at the two others. Apart from that the geographical position is also different, Bornö and Hättan being both situated well within the outer skerries, whereas Böttö is almost out in the open sea. Now, both from a theoretical point of view and according to previous experience the internal movements should have smaller amplitude some distance off the coast than within the fiords.

Another fact, of the greatest interest, borne out by these curves, is that the internal movements observed at places so differently situated occur practically at the same time. This coincidence makes it extremely improbable that these movements can be due to any progressive boundary wave-motion proceeding either parallel or at an angle to the coast line. If the phenomenon is at all of an undulatory character, it must be of the

FIG. 2.—Map of west coast of Sweden.

standing wave type with a node line more or less parallel to the coast. A progressive boundary wave should have a velocity of the order 0.50 meters per second, so that it would take about 12 hours to travel up the Gullmarfiord to Bornö.

A close scrutiny of the record, however, seems to indicate that the coincidence between the larger waves and troughs is not absolute, but that there is a small lag between the Bornö curve and the two others. A rough calculation shows that the Bornö curve is on an average 3 hours (± 1 hour) behind that of Hättan, and 4 hours (± 2 hours) after Böttö. This difference in phase being considerably smaller than the interval between two readings, its very existence must be open to some doubt. Nevertheless, it seems reasonable that the displacement

[4] MONTHLY WEATHER REVIEW, Ibid, p. 160

of the boundaries, whether it is caused by a standing wave or not, may be somewhat retarded by the friction of the horizontal currents against the comparatively shallow treshold at the entrance to the Gullmarfiord.

As regards the details visible in the curves, i. e., the variations of shorter duration and small amplitude, they are seen to be individually different at the different localities. But they are seen to be especially prominent in all three curves during the first week of August, when they also tend to show a diurnal periodicity. In the Hättan curves they are followed by a set of still shorter waves of semidiurnal period. The latter period also crops up in many other parts of the records, and there is little doubt as to its tidal character. As there were no observations made of the surface tides, it can not at present be decided whether these were in phase with the boundary waves, i. e., if these latter were primary or secondary tidal boundary waves, the latter type having already been studied in the Gullmarfiord by Zeilon.[5] Observations similar to these but of greater frequency will have to settle this question. It is, nevertheless, interesting to note, that the present method affords possibilities of studying tidal boundary waves of so small amplitude, that they would be quite inaccessible to the older technique.

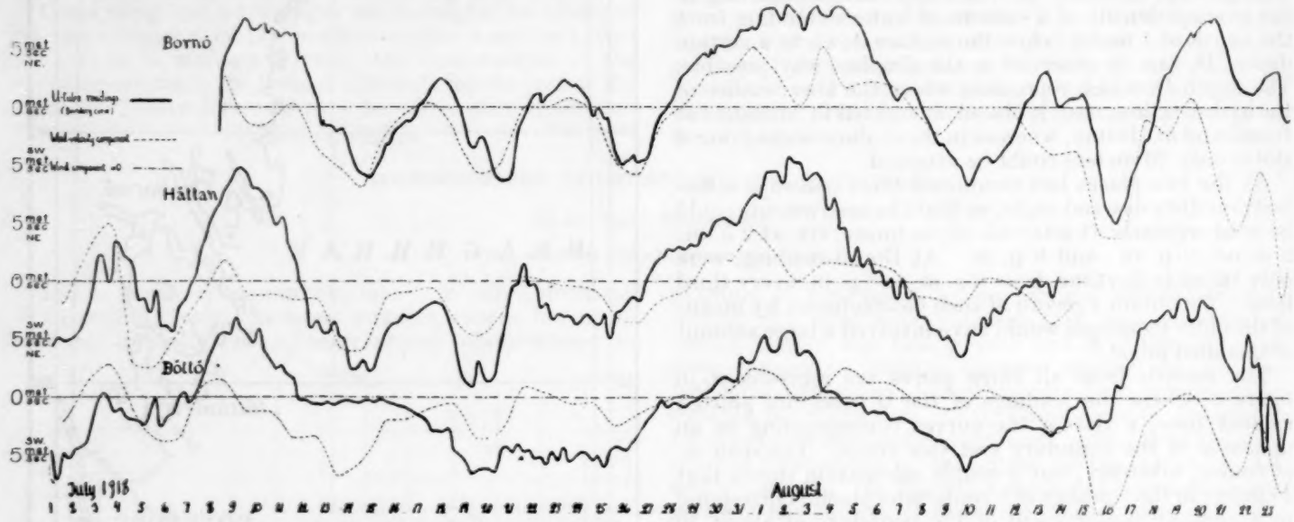

FIG. 3.—Relation of wind direction to the level of the upper boundary of dense sea water.

ORIGIN OF THE INTERNAL MOVEMENTS.

The central problem offered by these internal movements in the stratified coastal waters is naturally what their cause or causes may be. According to the theory propounded by O. Pettersson,[1] they form part of a *tidal* movement in the boundary, due to those long-periodic components in the tidal force which are denoted by the letters *Mm* and *Mf* in the harmonic analysis of the tides. These components, which are only able to produce minute fluctuations of the free surface should, according to this theory, evoke considerable effects in the slower reactive boundary, which effects may be further enhanced by resonance. By way of lending support to this explanation its author has drawn attention to the fact that the larger "waves" at Bornö very often occur at intervals of a fortnight (or a week), and that a certain train of waves has been found to repeat itself almost unaltered in shape after the lapse of a time equal to a multiple of the periods set out above.

Another explanation has also to be considered which attributes these internal movements to meteorological causes, viz, to variations in the local wind and the air pressure. It is a well-known fact, that a strong air current has a certain influence on stratified water, disturbing the equilibrium and producing a slanting position of the boundary surfaces. The system of currents generated in this manner has been ably studied and described by Sandström.[6]

Disregarding for the present the intricate dynamical part of the problem, we can say that any force which has for its immediate effect an inclination of the free surface will in stratified water tend to produce an inclination to the opposite side of the boundary. Taking the simplest case of a fiord with only two waterstrata of the densities $\delta < \Delta$ a constant slope of the surface equal to $\frac{dy}{dx} = C$ produced by a strong wind from the sea will ultimately produce a slope of the boundary of the magnitude $\frac{dy}{dx} = -C \times \frac{\delta}{\Delta - \delta}$. At a given point in the fiord we shall therefore expect the boundary to become finally depressed by the vertical distance $-H = -\frac{\delta}{\Delta - \delta} \times h$, where h is the rise of the free surface above its normal level at the same point.

The factor $\frac{\delta}{\Delta - \delta}$ varies considerably, but its average value is of the order 100 so that elevation of the surface of a few cm. would correspond to a depression of the boundary (at equilibrium) of as many meters. Now for every meter the boundary becomes displaced, roughly fifty million tons of water have to be transported through the orifice of the fiord in both directions. A certain time must therefore pass before the equilibrium value

[5] Svenska Hydr.-Biol. Komm. Skrifter, h. V.

[6] Ann. d. Hydrographie 1908, p. 9.

of the displacement has been (approximatively) attained. The variations in the level of the boundary must therefore inevitably lag behind the variations both of the wind and of the surface level. This lag will, in general, be greater in summer, when the factor $\frac{\delta}{\Delta-\delta}$ is usually small, than in winter when it is much larger.

In order to prove or disprove this meteorological theory, one must compare the boundary curve from Bornö with the simultaneous variations in the wind, or rather in the component of the wind velocity, which is parallel to the main direction of the fiord, i. e., SW. to NE., and also to compare it with the variations in the level of the free surface at Bornö. In order to give any results of value, this comparison must at least be extended over a whole year. I have gone through the rather laborious calculation required for that purpose for the whole of the year 1911, when the observations made at Bornö were more than usually complete. The boundary curve was obtained by calculating from each of the daily hydrographical soundings the depth at which water of 31 per mil salinity was found. For the surface level daily averages were calculated from the records of the maréograph at Bornö. The wind component (daily average) was found graphically from wind observations taken by anemometer three times a day at "Hållö" lighthouse near the entrance to the fiord. The three curves plotted against time are reproduced in figure 5 for the first quarter of 1911. W denotes the wind velocity in meters per second projected on the NE. (positive) to SW. (negative) direction. The surface curve S is drawn inverted, whereas the boundary curve B, is drawn in the ordinary way, the scale being 30 times smaller than that of the S curve. The conformity between the three curves is unmistakable, almost every increase in the wind component from the SW. being followed by a rise of the surface (a fall in the inverted curve) and a depression of the boundary. The latter

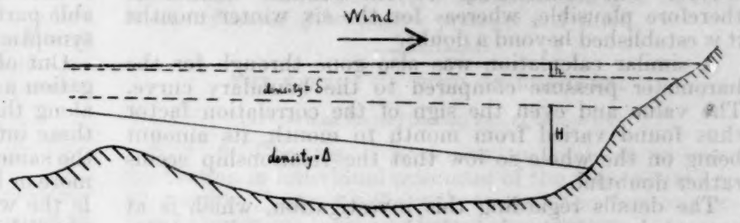

FIG. 4.—Influence of an up-fiord wind in depressing the surface of dense sea water on the bottom.

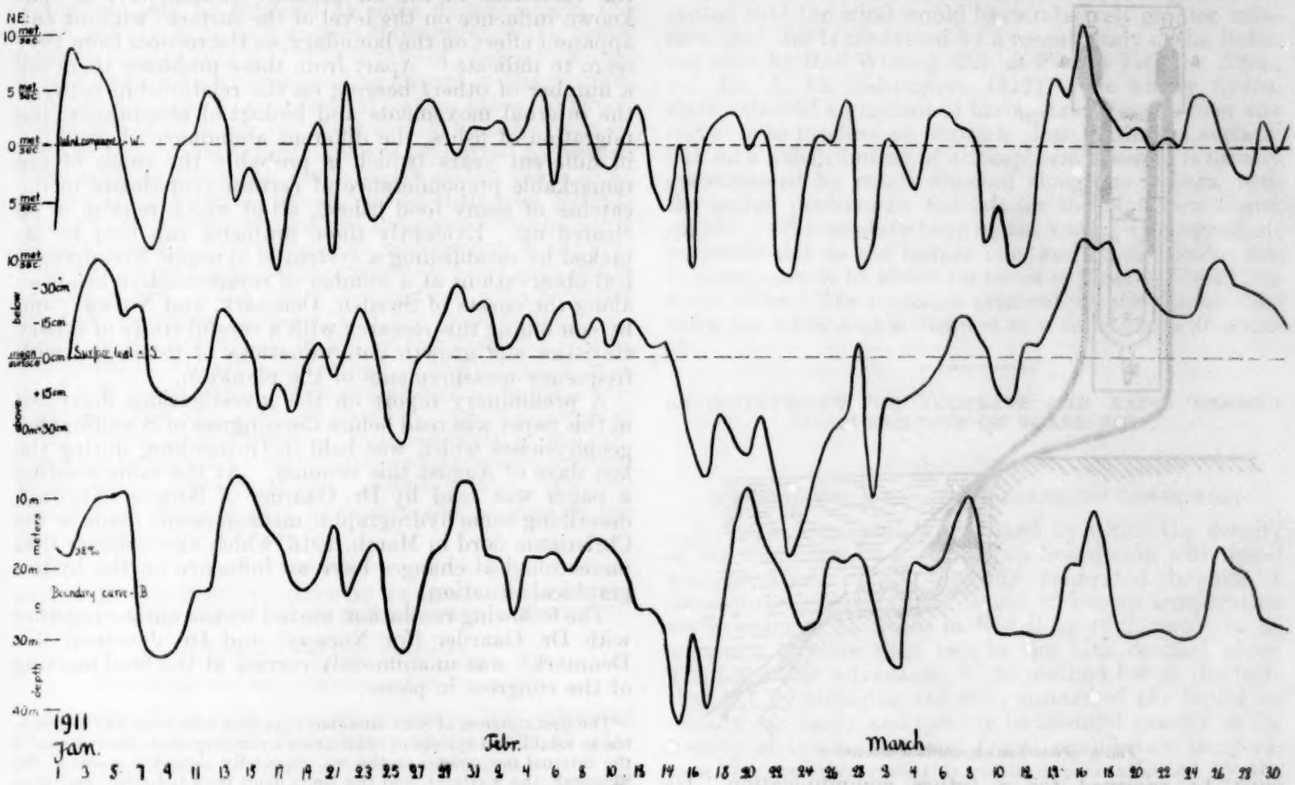

FIG. 5.—Relation of wind velocity to surface and dense sea-water levels.

change is, however, seen to be appreciably retarded against the two others. The opposite effect nearly invariably follows after an increase in the component from the NE. These results are in perfect accordance with the reasoning set out above. The same applies to the results obtained for the rest of the year with the exception that in summer the conformity between the W and S curve on one side and the B curve on the other is not so pronounced, whereas the lagging behind of the latter curve is apparently greater.

In order to test the relationship thus established, I have found it desirable to study the conformity by a more objective method. For this purpose I have calcu-

lated the correlation coefficients between the *W* and *B* curve for each month of the year by the method used by Wallén[1] and others for similar purposes. The results from these calculations show that the correlation coefficient, which is positive and comparatively high, varies from a maximum value in winter to a minimum in summer, the mean value for the months May–October being 0.65 whereas for the rest of the year it amounts to +0.30. The relationship for the summer months is therefore plausible, whereas for the six winter months it is established beyond a doubt.

A similar calculation was also gone through for the barometer pressure compared to the boundary curve. The value and even the sign of the correlation factor thus found varied from month to month, its amount being on the whole so low that the relationship seems rather doubtful.

The details regarding this investigation, which is at present being extended to the years preceding 1911,

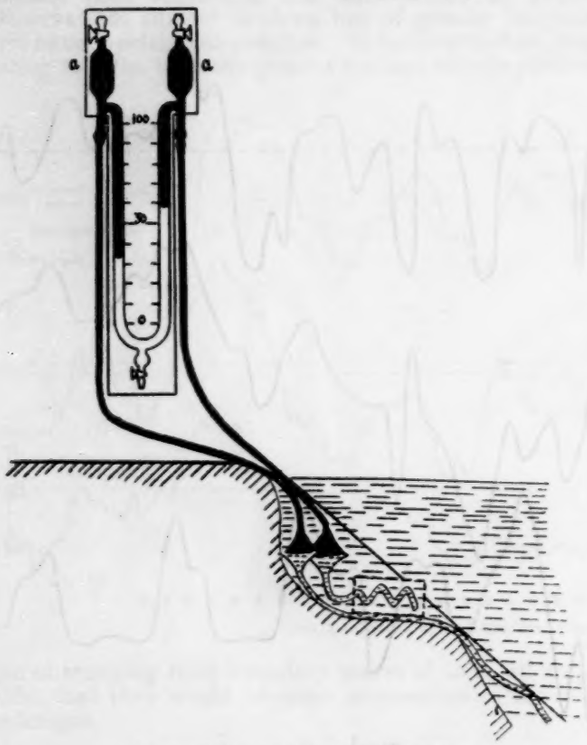

FIG. 6.—Pettersson's hydrostatic densimeter.

must be reserved for a future communication. Its results have, however, already proved beyond a doubt that the remarkable internal movements in the sea observed at Bornö have for one of their principal causes simultaneous variations in the wind velocity. It is of course an open question whether there may also be other influences, tidal or not, at play. The investigation, which is at present in progress may be hoped to throw some light also on this question.

In figure 3, giving the results from the synoptic observations of last summer, curves are also drawn (broken) which represent the NE./SW. component of the wind velocity, as observed at three lighthouses along the coast, viz, at "Hållö" near Bornö, at "Pater Noster" near Hättan, and at "Vinga" near Böttö. The relationship between the wind velocity and the movements of the boundary is best borne out by the Bornö curve, but is also fairly evident at the two other places. A similar comparison for the winter months would no doubt have given a much closer agreement. One may therefore say that the relationship between meterological phenomena and the internal movements in the sea, which has been discovered in the Bornö records from 1911, is also found to hold for the general movements comprising a considerable part of the coast, according to the results from this synoptic investigation.

Out of the results gained by this preliminary investigation a number of important questions arise. How far along the coasts of the Skagerak and the Kattegat are these internal movements of the same character and of the same phase? Is there really an undulatory element, more or less highly damped, present in these movements? Is the wind component at right angles to the fiord and parallel to the coast of no influence whatever? Why are the variations in the air pressure (which have a well-known influence on the level of the surface) without any apparent effect on the boundary, as the records from 1911 seem to indicate? Apart from these problems there are a number of others bearing on the relationship between the internal movements and biological phenomena, the migration of fishes, the different abundance of plankton in different years (which is probably the cause of the remarkable preponderance of certain year-classes in the catches of many food fishes), all of which require to be cleared up. Evidently these problems can best be attacked by establishing a system of synoptic hydrographical observations at a number of representative localities along the coasts of Sweden, Denmark, and Norway, and by combining this research with a careful study of fishery statistics and growth determinations of fishes and with frequency measurements of the plankton.

A preliminary report on the investigations described in this paper was read before the congress of Scandinavian geophysicists which was held in Gothenburg during the last days of August this summer. At the same meeting a paper was read by Dr. Gaarder of Bergen (Norway) describing some hydrographic measurements made in the Christiania fiord in March, 1916, which also indicate that meteorological changes have an influence on the hydrographical situation.

The following resolution, moved by the author together with Dr. Gaarder (for Norway) and Dr. Jacobsen (for Denmark), was unanimously carried at the final meeting of the congress in pleno:

> The first congress of Scandinavian Geophysicists considers it desirable to establish a system of continuous hydrographical observations of the internal movements in the sea, especially along the coasts of the Skagerak, the Kattegat, and the Belts, both from lightships and from observatories on the coast, the results from this survey to be compared with biological phenomena (fishery statistics and quantitative plankton measurements) and also with observations of the wind and the barometric pressure.

A committee of three (the movers of the resolution) was charged with the drawing up of a detailed program for this survey.

There is little doubt that internal movements in the sea similar to those described in this paper are also going on in stratified waters along the west coast of the North Atlantic. Synoptic investigations in these regions, which might be carried out at comparatively small costs and with little labor, would undoubtedly give results of considerable interest and would yield valuable contributions to the knowledge of the interaction between the atmosphere and the ocean.

[1] Sv. K. Vet. Akad. Handl. Bd. 57, No. 8.

SUMMARY.

Synoptic observations of hydrographic phenomena have been made during July and August of last summer at three different points on the west coast of Sweden. The results prove that internal movements closely resembling those found at Bornö occur practically simultaneously also at distant localities. These vertical displacements of the boundary are found to be closely related to simultaneous variations in the wind velocity, a fact which has also been proved by a separate investigation of the Bornö records for 1911. The establishment of a permanent system of synoptic observations in the sea found the coasts of Scandinavia is at present in progress.

APPENDIX.

The hydrostatic densimeter described in a preceding paper has been modified in the following details so as to be better adapted for localities where sufficiently deep water can only be attained at some distance from the shore, and also to be independant of temperatures far below freezing point. (Fig. 6.) The U tube of glass is mounted upside down with a corresponding change in the position of its air traps *A*, *A*, and communication tubes, to which the submerged tubes are attached. The latter are of lead, one-fourth inch wide, and are supported by bronze wires running along the whole length of the tubes so as to save them from the strain due to their own weight. About 1 meter below the surface there is a biconical brass vessel of about 1 liter inserted in each branch of the system. The upper half of these vessels is filled with liquid paraffin (black in the figure), colored red with a scarlet dyestuff insoluble in water, and the same fluid is contained in the upper part of the system from the vessels and upward. Only the lower half of the U tube itself is filled with a mixture of water and alcohol of the approximate density 0.85 (4 parts of water to 6 parts of alcohol) which serves as index fluid. The sensibility of the system may be varied by taking other concentrations of the water-alcohol mixture (within certain limits). The instrument is quite as easy to mount and to read as the type previously described.

NOTES ON THE FLUCTUATIONS OF MEAN SEA LEVEL IN RELATION TO VARIATIONS IN BAROMETRIC PRESSURE.

By Capt. T. BEDFORD FRANKLIN.

[Abstract from Jour. Scottish Met'l Soc., vol. 18, 1918, pp. 30-31.]

A study of the data from self-recording tide gauges at Dunbar, Newlyn, and Felixstowe by Col. Sir Charles Close brought him to the following conclusions:

1. That the effect of the local variation of pressure on sea level is opposite in sign to, and 13.25 times the magnitude of, the barometric variation—that is, the ratio is the same as the ratio of the specific gravity of mercury to that of sea water. [The actual ratio varies from about 7–20.]

2. That there is an annual tide—the cause at present unknown—having an amplitude of 6 inches, with a maximum in November and a minimum in April.

As suggested in 1914 by Prof. D'Arcy W. Thompson, the discrepancies between the tidal variation and barometric curves may be accounted for by considering atmospheric pressure and winds together. For Newlyn, by assuming that the effect of the wind either in piling up the water or in pushing it out to sea is proportional to its pressure in pounds per square foot, such that the effect in inches of sea level is about 1.5 times the inshore or offshore component of the wind pressure, it is possible to account closely for the differences between the hydrostatic and observed effects. This effect on seven occasions cited was 1 to 7.5 inches.

It would, therefore, appear that by applying the appropriate wind correction the two curves may be made very nearly to fall upon each other, and that for the limited period under observation—December, 1916, to June, 1917—*the sea level responded immediately to the combined influences of barometric pressure and wind.*

THE EFFECT OF WIND ON SEA-LEVEL.

[Extract from Nature (London) Feb. 13, 1919, p. 471.]

* * * Changes of level due to winds cause some fluctuation in individual estimates of the ratio (from 7 to 20, roughly), but not sufficiently to mask the close connection between sea-level and barometric pressure.

In a narrow landlocked sea, however, it might be expected that the wind would have relatively greater influence, and this is confirmed by a recent study of the Baltic sea level by Rolf Witting (*Öfv. af Finska Vet.-Soc. Förh.*, vol. lix, A, 13. Helsingfors, 1917). The purely hydrostatic effect of a gradient of barometric pressure over any region is to produce an opposite slope of the sea surface; but such a distribution of atmospheric pressure is usually accompanied by winds directed along the isobars, with the higher pressure on the left (in the Northern Hemisphere). This tends to heap up the waters with a gradient perpendicular to the former one, and in the Baltic this slope appears to be about 1.8 times as great as the hydrostatic slope. The resultant gradient is rather more than twice the latter and is inclined to it in azimuth at about 55°.

AN INSTRUMENT FOR ACCURATE AND RAPID DENSITY MEASUREMENTS ON BOARD SHIP.

By A. L. THURAS.

[Author's summary, from Journ. Wash. Acad. Sci., 1917, 7: 605-612, 2 figs.]

A simple apparatus is described by which the density of sea water can be measured on board ship with speed and precision. With carefully calibrated bobbins a density measurement of a liquid of known temperature coefficient can be made in less than 10 minutes to an accuracy of more than two in the fifth decimal place. The particular advantage of the method lies in the facts that (1) by changing the temperature of the liquid its density can easily and quickly be brought exactly to the density of the bobbin, and (2) at equilibrium temperature the sensitivity of the method is unaffected by the motion of the vessel, the liquid and bobbin having the same density.

AN ELECTRICAL INSTRUMENT FOR RECORDING SEA-WATER SALINITY.

By ERNEST E. WEIBEL and ALBERT L. THURAS.

[Author's summary, from Journ. Wash. Acad. Sci., 1918, 8; 145-153, 3 figs.]

An apparatus to give a continuous record of sea-water salinity by the measurement of its electrical conductivity is described. A pair of electrolytic cells has been designed which when used with a suitable alternating-current galvanometer will give satisfactory operation in connection with a recorder. The temperature compensation is obtained by placing both cells, which are in the

two arms of a Wheatstone bridge, in a uniform temperature bath.

WILLIAM ALLINGHAM.

William Allingham, for many years principal assistant in the marine branch of the Meteorological Office, died suddenly January 24, 1919, at the age of 69. His early life was spent at sea, but, owing to a disabling accident, he obtained in the early seventies a post in the Admiralty, then in 1875 he was transferred to the staff of the Meteorological Office. In addition to a practical knowledge of navigation and meteorology, Allingham was gifted with considerable literary ability. His chief works were the compilation of a Manual of Marine Meteorology, and in conjunction with Capt. Wilson-Barker, a treatise on Navigation, Practical and Theoretical.—*From Symons's Met'l Mag., Feb. 1919, p. 4.*

CAPTAIN MELVILLE WILLIS CAMPBELL HEPWORTH.

Apr. 27, 1849–Feb. 25, 1919.

The death of Capt. M. W. C. Hepworth, following so soon after that of Mr. Allingham, is a serious loss to the Marine Division of the Meteorological Office, of which he had been Superintendent since 1899. The Monthly Meteorological Charts of the North Atlantic and Mediterranean, as well as of the East Indian seas, were initiated during his tenure of office, and the later editions of the Barometer Manual for the Use of Seamen and the Seaman's Handbook of Meteorology were compiled under his direction and attained a large circulation. Capt. Hepworth was much interested in marine biology and in the temperature and salinity of the sea. For the many years while at sea he made a study of meteorology which prepared him for his official position.—*From Nature (London) Mar. 6, 1919, p. 8 and Symons's Met'l Mag., 1919, pp. 13–14.*

RELATION BETWEEN VEGETATIVE AND FROSTLESS PERIODS.

By JOSEPH BURTON KINCER, Meteorologist.

[Dated: Division of Agricultural Meteorology, Weather Bureau, Washington, D. C., Jan. 13, 1919.]

The two most important climatic elements with reference to plant growth are temperature and precipitation. Of these, temperature is the more effective in establishing the geographic areas within which certain plants thrive best on the one hand, or even fail to mature on the other, and it also determines the period of the year during which growth is possible.

In any study of plant growth as affected by temperature, there are two important phenomena that may be considered as constituting critical or basic points from which reckonings must be made; these are the vegetative temperature and frost. The first defines the potential period of plant growth, which is determined by the date in spring when the temperature rises sufficiently high to render active the protoplasmic content of vegetable cells, and thus produces growth, and the date in fall when it falls below this point and growth ceases. The frostless period is determined by the dates of the last killing frost in spring and the first in autumn. It is the object of this paper to study briefly the relation of these two basic periods, and their variations in length in different sections of the United States.

The average growing season as determined by frost occurrence is understood to be the number of days between the average date of last killing frost in spring and the first in autumn, but some plants are more susceptible to frost damage than others and consequently the growing season as thus defined varies in length in the same locality for different plants. This is also true for the vegetative period as determined by the amount of heat necessary to produce plant growth, considered independently of the occurrence of killing frost. It has long been known, however, that for most plants in temperate climates, the vegetative or active period begins in spring, as a general rule, when the mean daily temperature rises to 6° C. (42.8° F.), and ends in autumn when it falls below that value. These limits have been adopted for the purpose of this study of the relation of the vegetative to the frostless period.

Chart I shows the average dates in spring when the mean daily temperature rises to 43° and Chart II the dates in autumn when it falls below that value. The vegetative period, represented by the average number of days when the mean daily temperature is 43° or higher, is shown for different sections of the country by Chart III. This period is not the same, of course, for each year, but varies from year to year, as does the frostless season or any other period determined by the average dates on which phenomena occur. From the Rocky Mountains westward the charts are highly generalized, owing to the great variation in the topographic features of that section of the country.

Chart I shows that the advent of the vegetative period in an average year ranges from the first of February in the northern portion of the Gulf States to May 1 in extreme upper Michigan and northern New England. Chart II indicates that this period comes to an end, on the average, in the extreme northern districts about the middle of October, but it continues till the end of the year in the South. Chart III shows that the length of the period ranges from less than 180 days in the extreme north and in the central and northern portions of the Rocky Mountain region, to 365 days in the south Atlantic and Gulf districts, and also in the central and southern Pacific coast sections. (The latest frost charts are those appearing in the frost section of the Atlas of American Agriculture, recently published.[1] See also "The Probable Growing Season," by William Gardner Reed, MONTHLY WEATHER REVIEW, Sept., 1916, **44**, 509–512.)

The normal daily march of temperature is closely allied with the annual march in establishing the vegetative period. For example: If we assume that most vegetation is awakened from the dormant state when the daily mean temperature rises to 43°, it is evident that prior to the date on which this occurs, the temperature during the warmer portion of the day would be sufficiently high to produce growth and consequently, it would appear, that some growth actually begins before the mean temperature rises to the vegetative point (on the average, the temperature during approximately one-half of the day is higher than the daily mean). This, however, is true only in a limited degree, as will be evidenced by a careful consideration of the amplitude of the daily extremes of temperature. This amplitude varies with the moisture content of the air and its attending phenomena, with the latitude, and also with the sea-

[1] Advance sheets 2, pl. II, sec. 1; issued, 1918; 34 x 48 cm., 12 pp., 12 colored maps, 10 weather maps, 10 graphs. Selected bibliography. Review in M.W. R. 1918, 46:516–517.

sons, being considerably greater in the warmer portion of the year than during the colder months. During the transition season, that is the time of passing from the nonvegetative period to the vegetative period in spring, and vice versa in fall, the amplitude of the daily temperature march is quite uniform in most sections of the country, averging about twenty degrees F. It will thus be seen that until the mean daily temperature rises to 43°, the daily minima, as a rule, fall below the freezing point, which precludes any appreciable permanent growth. The fact that the mean minimum temperature rises above the frost line (32°) coincidently with the rise to 43° in the mean temperature probably has a more direct bearing on the significance of the latter as the vegetative value than has the fact that the temperature stays above 43° on the average for half the time during the day.

Owing to the fact that normal mean daily temperature values are available for only a limited number of stations, and do not appear in the periodical publications of the Weather Bureau, botanists frequently determine the limits of the vegetative period by considering all months with a mean temperature of 49° or higher as growing months and those with temperatures below that value as nonvegetative months.[2]

This assumes, of course, that when the mean monthly temperature is as high as 49° the entire month, approximately, will have a mean daily temperature of 43° or higher. The method is often unsatisfactory, however, as it is evident that by its use one degree in the mean monthly temperature (48° instead of 49°) would make a month's difference in the length of the estimated vegetative period, while there would be actually a difference of only about three days. Moreover, this relation holds good only when the temperature is near the vegetative value (from 40° to 50°) during the months of March and April in spring, and October and November in fall, when the changes in temperature are rapid. With a mean monthly temperature as low as 45° from December to February, the mean daily values usually remain above the vegetative point throughout the month, but with a mean of 45° in March or April that value is not reached until about the 10th, while in October and November with a mean monthly temperature of 45°, the mean daily temperature falls below the vegetative point about the 22d.

In computing the average vegetative period from monthly temperatures, it is preferable to estimate the actual dates by means of a simple diagram as shown in figure 1. This chart may be used for that purpose by indicating thereon for any station the mean monthly temperature for each of the two months for which the values are nearest the vegetative point (43° F.), when a straight line drawn from one point to the other will intersect the vegetative temperature line (43°) at the approximate date on which the temperature rises to that value in spring or falls below it in fall. The mean monthly temperature should be considered as the value at the middle of the month or at the point where the vertical dash line intersects the proper horizontal temperature line. Example: The mean monthly temperature at Columbus, Ohio, for March is 39° and for April, 51°. By drawing a straight line between the point where the 39° temperature line and the dotted line for March intersect, to the point where the 51° line and the middle of April coincide, it crosses the vegetative temperature line (43°) at a point indicating approximately March 25, which represents the beginning of the vegetative period at Columbus. The chart may be used also for the fall months by reading from right to left as indicated by the arrangement of months at the bottom of the chart.

As the theoretical period of plant growth extends from the date on which the mean daily temperature in its annual march rises to 43°, to the date on which it falls below that value, it is of interest to study the relation in length between this period and that usually designated as the growing season, or the period between the spring and fall frost dates. As the average frostless period in most of the country is considerably shorter than the vegetative period, as is shown by the accompanying charts, it follows that the vegetative period is shortened by the occurrence of frost, at least in so far as vegetation that is susceptible to frost damage or destruction is concerned. Except in portions of the Florida Peninsula

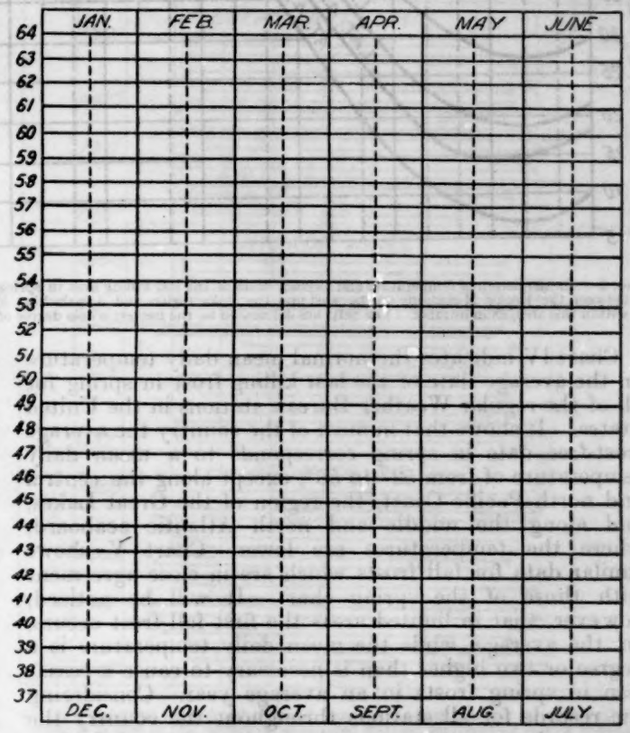

FIG. 1.—Diagram for determining vegetative temperature and frost dates from mean monthly temperatures.

and in some favored localities in California, frost occurs during each winter. The length of the period during which it may be expected varies with the latitude and altitude, especially the former, in most sections east of the Rocky Mountains. After the first killing frost in fall, frost occurs at irregular intervals until the annual spring rise in temperature reaches a certain value, when it ceases on the average until approximately that value is again reached in the fall recession of temperature. These mean daily temperature values which coincide with the cessation of frosts in spring and their resumption in fall are remarkably uniform, not only under different topographic conditions, but also over large geographic areas. Away from marine influence, they are mostly from 9° to 13° above the vegetative temperature values, as before defined.

[2] See Zon, Meteorological Observations in connection with botanical geography, agriculture, and forestry, MONTHLY WEATHER REVIEW, April, 1914, 42:217-223.

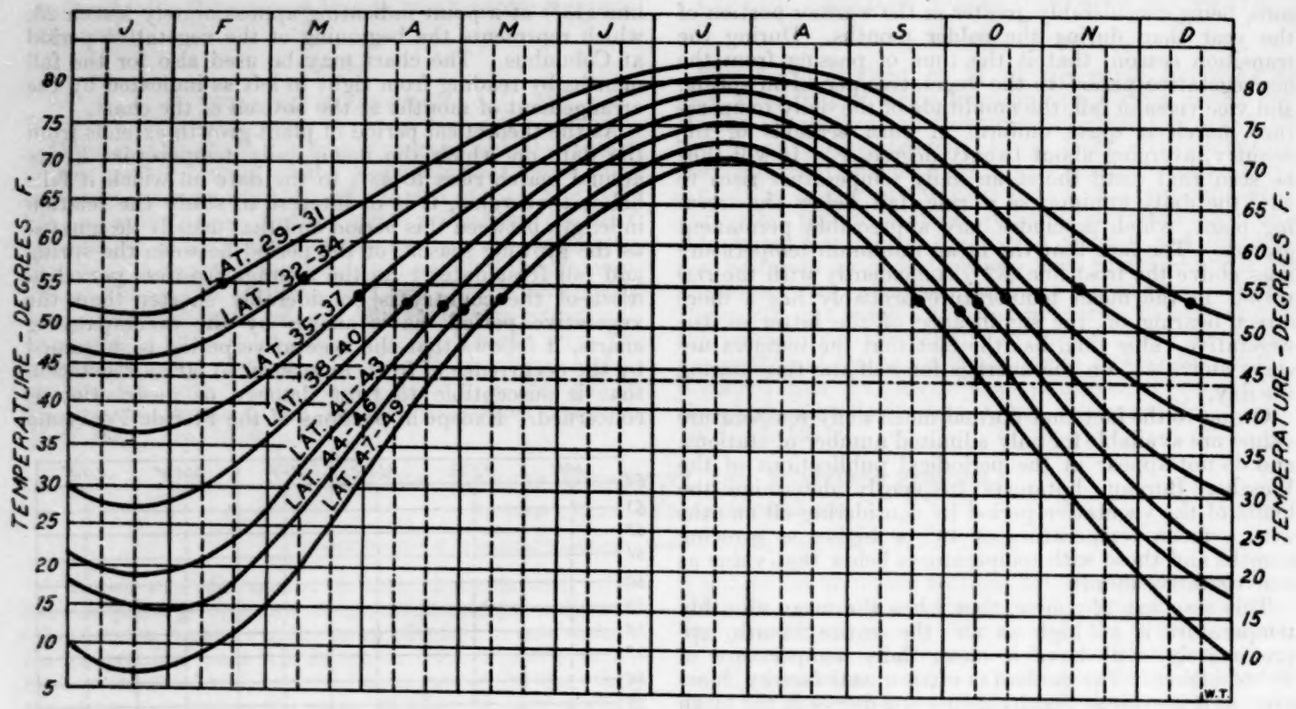

FIG. 2.—Annual march of temperature and average dates of the last killing frost in spring and the first in autumn, for successive belts of 3° latitude in width, from 29° to 49°, between the Rocky Mountains on the west and the Lake region and Appalachian Mountains on the east, based on the records of all regular Weather Bureau stations within this area, 68 in number. The belts are delineated to the nearest whole degree of latitude. Temperature ——. Frost dates ●.

Chart IV indicates the normal mean daily temperature on the average date of the last killing frost in spring for all of the regular Weather Bureau stations in the United States. It shows that in most of the country the average frost-free date in spring corresponds to a mean daily temperature of from 52° to 56°, except along the central and north Pacific Coast, the region of the Great Lakes, and along the middle and north Atlantic seaboard, where the temperatures are lower. Chart V shows similar data for fall frosts which are in close agreement with those of the spring chart. It will be noticed, however, that in limited areas the first fall frost occurs, on the average, while the mean daily temperature is a degree or two higher than is necessary to cause a cessation in spring frosts in an average year. Considering the records for all stations throughout the country the mean daily temperature on the average date of the last killing frost in spring is 52.1°, and on the average date of the first in fall it is 52.6°. By areas, the spring and fall averages are as follows:

	Spring.	Fall.
	°F	°F
North Atlantic States	48.0	50.6
South Atlantic States	53.3	53.8
Gulf States	55.7	56.0
Ohio Valley and Tennessee	53.2	53.1
Lake Region	47.6	48.9
Mississippi Valley	52.6	53.5
Great Plains	53.2	55.2

It is interesting to note the similarity of these temperatures over large areas, even extending from the northern to the southern boundaries of the country. On Chart IV, for example, there is shown a wide belt extending from the Gulf of Mexico northwestward through the Plains States to the Canadian boundary in which frost ceases in spring, as a rule, when the temperature in its annual march rises to 54° or 55° F. The winters are long and severe in the northern portion of this belt, and the soil usually freezes to great depths, but in the extreme south very little winter is in evidence and the vegetative period extends throughout the year. Notwithstanding these great differences in winter conditions, when the normal mean daily temperature in spring rises to 55°, frost ceases, on the average, in the extreme north as well as in the south; the difference in the average time of occurrence of the last killing frost in spring along the central Gulf coast and in northern North Dakota is nearly 4 months. Attention is also invited to the comparatively low temperature values appearing along the central and northern Pacific coast, the Lake region, and the north Atlantic coast, where the water influence is felt in warding off frost. There is a similar area shown to the leeward of the central and southern Appalachian Mountains in Virginia and North Carolina where frost ceases on the average with a lower mean temperature in spring and does not occur with as high temperatures in fall as in the surrounding regions.

Owing to the fact that these temperatures corresponding to the average frost dates are so uniform, it is possible to determine very closely the average frost dates from the mean daily temperatures. In the case of cooperative and other stations for which daily values are not available the dates can be closely approximated from the mean monthly temperatures by the use of figure 1 and Charts IV and V, the charts showing for different localities the average frost temperature values. The method to be used is the same as described for finding the beginning and ending of the vegetative period, except that the frost temperature values shown on Charts IV and V must be substituted for the vegetative temperature (43°). Example: Chart IV shows that the average spring frost

temperature in the vicinity of Ithaca, N. Y., is 52°. Ithaca has a mean monthly temperature for April of 44°, and for May 57°. A straight line drawn from the proper points on the chart intersects the frost temperature line for that locality (52°) at approximately May 5, which indicates the average date of last killing frost in spring at that point. Fall frost dates may be found in the same manner by reading the chart from right to left, as indicated previously. By this method frost dates can be determined from cooperative or other stations that may have temperature but not reliable frost records. In addition, owing to the smaller variations in the mean monthly temperature than in the actual frost dates from

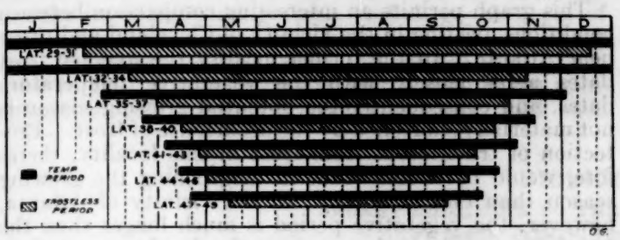

FIG. 3.—Average period of the year with mean daily temperature 43° or above and the average frostless period (from the average date of the last killing frost in spring to the first in autumn) for the same latitudinal belts used and explained in Fig. 2.

year to year, the average frost dates for short record stations can often be determined more accurately from the mean temperature than from the frost records themselves; that is, the average date that would be obtained if longer records were available. For example, the

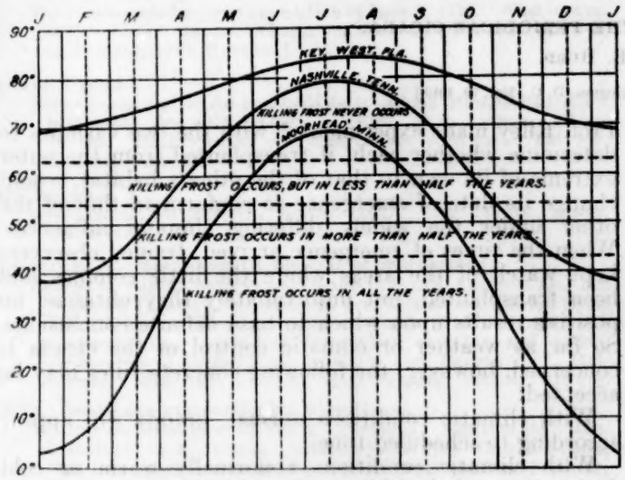

FIG. 4.—Relation of mean daily temperature to the occurrence of killing frost.

average date of the first killing frost in fall at Washington, D. C., based on a 45-year record, 1874 to 1918, is October 22. If we divide this into nine 5-year periods and determine the average frost date for each of these by the temperature method described, the result in no case differs from the 45-year mean by more than four days, while the actual averages computed from the recorded frost dates for the respective periods vary from October 16 to November 2. Again, if only the 5-year record from 1914 to 1918 were available for Washington, the recorded dates of last killing frost in spring would give the average date as March 29, but the mean temperature for this period gives an indication of April 7 as the average date, when determined as indicated. The 45-year average is April 8.

A picture of the relation of frost occurrence to mean temperatures is afforded by figure 4. This graph shows that, broadly speaking, the following general law is applicable, the temperature values differing only slightly for different localities and for the spring and fall seasons. Killing frost occurs each year in spring until the normal mean daily temperature rises to approximately 43° (the vegetative value). After this temperature is reached, frost does not occur in all the years, but does occur in more than half the years until the average temperature reaches 54°, which corresponds in date to the average occurrence of the last frost in spring. Thereafter killing frost may be expected with less frequency, or in less than half the years, until the mean daily temperature rises to approxi-

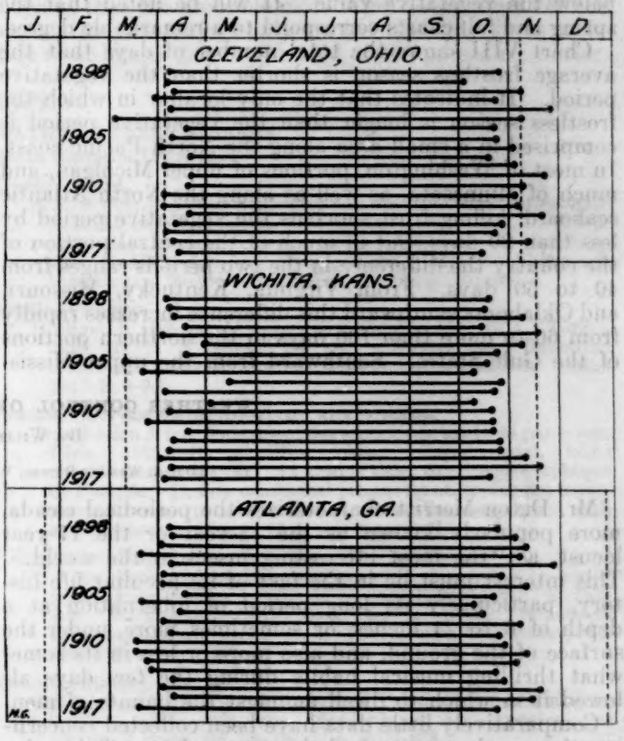

FIG. 5.—Variations of the frostless period from the vegetative period for each of the 20 years from 1898 to 1917, inclusive, at selected stations, representing regions of small, moderate, and large variations. The dots represent the dates of the last killing frost in spring and the first in fall, and the lines connecting the dots show the length of the frostless season for the respective years. The dates on which the vegetative period is reached in spring and passed in fall are shown by the vertical dash lines.

mately 63°, after which it is not experienced. This holds good also for fall frost.

Figure 2 shows the annual march of temperature and the average dates of the last killing frost in spring and and the first in fall for successive belts three degrees of latitude in width, from latitude 29° to 49°, between the Rocky Mountains on the west and the Lake region and the Appalachian Mountains on the east, based on the records of 68 regular Weather Bureau stations within this area. The curved lines show the annual march of temperature for the respective belts, based on the average of all records within each belt, which is considered to the nearest whole degree of latitude, and the dots indicate the average frost dates. A horizontal dash line has been drawn to show the vegetative temperature value (43°). It will be seen that the frost dots are disposed horizontally

in an orderly arrangement and are considerably higher than the vegetative temperature line. In figure 3 the average length of the potential growth, or vegetative, period is compared with the average frostless period for the same belts that were used in the construction of figure 2. This shows graphically for the several belts the effect of killing frost in shortening the potential vegetative period in so far as plants that are susceptible to frost damage or destruction are concerned.

Charts VI and VII show, respectively, the average number of days by which the potential growing season is shortened in spring and in fall by frost. Chart VI indicates the average number of days in spring after the vegetative temperature period is reached until the average date of the last killing frost, while Chart VII shows the average number of days the first killing frost in fall occurs before the mean daily temperature falls below the vegetative value. It will be noted that the spring and fall charts correspond to a remarkable degree.

Chart VIII shows the total number of days that the average frostless season is shorter than the vegetative period. It indicates that the only locality in which the frostless season is longer than the vegetative period is comprised in a small area along the North Pacific coast. In most of Washington, portions of upper Michigan, and much of Minnesota, as well as along the North Atlantic seaboard, killing frost shortens the vegetative period by less than 20 days, but in much of the central portion of the country the difference in the two periods ranges from 40 to 60 days. From Virginia, Kentucky, Missouri, and Oklahoma southward this difference increases rapidly from 60 to more than 100 days in the northern portions of the Gulf States. Southward from the upper Mississippi Valley to southern Arkansas the difference increases from 20 to 100 days, or from less than one to more than 3 months.

Figure 5 shows for Cleveland, Ohio; Wichita, Kans.; and Atlanta, Ga., representing, respectively, regions of small, moderate, and large variations, the relation of the frostless season to the vegetative period for each of the 20 years from 1898 to 1917, inclusive. The dots represent the dates of the last killing frost in spring and the first in fall and the horizontal lines connecting the dots show the length of the frostless season for each year. The average dates on which the vegetative period is reached in spring and passed in fall are shown by the vertical dash lines.

This graph permits an interesting comparison between conditions existing in the vicinity of Cleveland and those near Atlanta. In the former locality the average frost dates agree closely with the vegetative temperature dates, and consequently the potential growing season is not materially shortened by the occurrence of frost. Protection of truck crops from frost in this locality, therefore, would be of less value in lengthening the growing season than farther south. In the vicinity of Atlanta, however, the vegetative period is much longer than the frostless period, and consequently hardy vegetation, such as winter grains and grasses, has a much longer growing season than has vegetation susceptible to frost damage. It follows that frost protection can be much more profitably practiced in northern Georgia than in northern Ohio. South of Atlanta, the mean daily temperatures remain above the vegetative value throughout the year, which makes an even greater contrast between the potential vegetative and frostless seasons.

WEATHER CONTROL OF THE PERIODICAL CICADA.

By WILLIS E. HURD.

[Dated: Weather Bureau, Washington, D. C., Mar. 29, 1919.]

Mr. Dixon Merritt characterizes the periodical cicada, more popularly known as the 13-year or the 17-year locust, as "the most interesting insect in the world."[1] This interest must lie in the fact of its peculiar life history, particularly its long period of hibernation at a depth of 6 to 24 inches, or sometimes more, under the surface of the ground, and also more or less in its somewhat thrilling musical habits during the few days allowed it in which to dwell amongst the haunts of men.

Comparatively little data have been collected concerning the weather control of this insect, but sufficient information is at hand to permit of some generalizations as well as theories on the subject. The 17-year cicada is largely an inhabitant of the northern States, while its 13-year relative is quite as exclusively confined to the South. Since these insects are physically identical, except in one or two minute particulars, it was very reasonably suggested that the southern type probably emerges from the nymph state four years the earlier only because of the more favoring climate, since the warmer the weather in general the more is the development of the individual facilitated. However, there are no intermediate zones of development graduating from one of a 13-year period along the southern borders of the Gulf States, to another of a 17-year period along the Canadian border, and the two brood types do not change the length of their hibernation periods, except for slight individual and local diversions, even in the median regions where they overlap. As early as 1881 and 1885 Prof. Riley made experiments[2] with the two varieties to determine whether each, if transplanted from the outer extreme of its own to that of the other's habitat, would change its date of emergence to conform to that of the other under the widely differing climatic influences. When the times of emergence arrived, trained observers kept watch of the areas where the little colonies had been transplanted, but unfortunately they obtained no positive results upon which to base definite conclusions. So far as weather or climatic control of the cicada is concerned, however, the following concrete rules may be accepted:

With climatic conditions normal, broods will appear according to scheduled time.

With climatic conditions abnormally warm or cold during the period of hibernation the broods may appear a few days earlier or later than the scheduled time.

In addition, cool weather intervening while the broods are emerging will cause a delay in the appearance of those not already arrived.[3]

The southernmost members of a brood will sometimes appear from a few days to three or four weeks in advance of the northernmost, depending upon temperature conditions.

Some interesting instances of accelerated emergence have been observed. At Belvidere, Ill.,[4] an old apple orchard, in which a swarm of cicadas had lived in 1888, was grubbed up a few years later and the ground covered

[1] The "17-Year Locust" in 1919. U. S. Dept. of Agr. Circ. 127, p. 3.

[2] The Periodical Cicada. C. L. Marlatt. Bur. of Ent. Bul. No. 71, pp. 18-20, 1907.
[3] Ibid., p. 90.
[4] Ibid., p. 24.

with greenhouses. This area was thus artificially warmed and protected, and the hibernating insects indwelling due to emerge in 1905, appeared a year earlier in quantities in the greenhouses. At Alton, Ill.,[5] a certain soil area was equipped with underground flues for forcing vegetables, and the heat caused the cicadas within range of its influence to appear in March instead of in May.

Frost may play an important part in the control of this insect. The story of a 13-year swarm known as brood 19, which appeared in Tennessee in 1894, is an interesting one, and the concluding chapter is expected to be read in 1920. Light frosts occurred in the eastern and central portions of the State on May 29, 1894, while the cicadas were coming forth, and large numbers of the tender arrivals perished from cold without laying eggs. Singularly enough, upon the reappearance of the brood in 1907, on the 28th of May, frosts were even more widespread than in the preceding instance, and such numbers of the insects were destroyed that very few if any of their descendants may remain to greet the interested observers from the Department of Agriculture who will watch for them next year.

There are many cicada broods in various stages of development under the soil of the United States, and the largest of the 17-year broods is preparing to appear over a considerable territory east of the Mississippi River this spring. The nymphs are already lying near the surface in and about the District of Columbia, awaiting the time to crawl forth into the daylight and scramble for trees and bushes in which to shed their pupal skins. The usual time of appearance is during the last week or ten days of May, but some entomologists are wondering if they may not arrive a few days earlier than usual this spring, owing to the extraordinarily open winter. Still, it is also suggested, and that by one of our meteorologists, that the probable more rapid development of the insects this year may go only toward offsetting the as probable retardation due to the cold of the preceding winter.

[5] Ibid., p. 90.

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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Heidke, P[aul]. Meteorologische Beobachtungen aus Kamerun. Teil 1. Zusamenstellung der Monatsmittel bis zum Jahre 1912 an 40 Stationen höherer Ordnung. p. 209–335. (3. H.)

Langbeck. Die Niederschlagsregistrierungen an der Pflanzstätte Idenau (Sanje) am Kamerungebirge von April 1911 bis März 1912. p. 335–337. (3. H.)

Marquardsen, H[ugo]. Bericht über das meteorologische Beobachtungswesen im Schutzgebiet Deutsch-Neuguinea. p. 360–366. (4. Heft.)

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Schlikker, Bernhard. Beitrag zu den Regenverhältnissen im küstennahen Gebiete von Deutsch-Ostafrika. p. 1–41. (1. H.) [With rainfall chart of eastern German E. Africa.]

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Jahresbericht über das meteorologische Beobachtungswesen im sudwestafrikanischen Schutzgebiet fur die Zeit vom 1. Juli 1912 bis 30. Juni 1913. Bearbeitet im Gouvernement von Deutsch-Sudwestafrika. p. 75–98. (2. H.)

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Marquardsen, Hugo. Regenfall im Kongo-Becken. p. 35–38. (1. H.) [With monthly rainfall data for 35 stations and isohyetal chart covering approximately the Belgian Congo.]

Bachmann, Fr. Klima-Tabellen aus Elisabethville in Katanga. p. 130–134. (3. H.)

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Heidke, P[aul]. Meteorolgische Beobachtungen aus Deutsch-Neuguinea einschliesslich des Inselgebiets der Karolinon, Palau und Marianen sowie der Marshall-, Brown- und Providence-Inseln. Teil I. Zusammenstellung der Monatsmittel bis zum Jahre 1913 an 30 Stationen höherer Ordnung und 13 Regenmessstationen. p. 3–170. (1. H.) [Exhaustive discussion and digest of the available meteorological data for the regions named in the title.]

Marquardsen, H[ugo]. Der gegenwärtige Stand der klimatischen Erforschung Angolas. p. 330–338. (2. H.) [With collected data for the stations and a rainfall map of Angola and adjacent regions.]

Niehaff, Kurt. Oberflächengestaltung, Niederschlag und Abfluss des Niger und seiner Nachbargebiete. Auf Grund einer zweijährigen Studienreise. p. 339–403. (3. H.) [With rainfall chart of West Africa, and graphs of yearly rainfall and run-off. Also normal yearly rainfall for 225 stations, reduced to the period 1901–12.]

Sprigade, Paul. Die französische Kolonie Ober-Senegal und Niger. p. 427–530. (4. H.) [Climate p. 452–9. Includes tabulated climatic statistics for the stations in Upper Senegal and Niger.]

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Ruppel, Julius. Nord-Rhodesien. Natürliche und wirtschaftliche Verhältnisse. Verkehrswesen. Verwaltung und Finanzwesen. p. 203–231. (3/4. H.) [Climate, p. 205–6.]

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Behrmann, Walter. Der Sepik (Kaiserin-Augusta-Fluss) und sein Stromgebiet. p. 1–100. (Nr. 12.) [Climate, p. 78–85.]

Hassert, Kurt. Beiträge zur Landeskunde der Grashochländer Nordwest-Kameruns. Erster Teil: physische Geographie. p. 1–144. (Nr. 13.) [Climate, p. 76–92.]

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Köppen, Wladimir. Klassifikation der Klimate nach Temperatur, Niederschlag und Jahreslauf. p. 193–203.

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Brand, W. Reichweite des Geschützdonners nach Kriegsbeobachtungen [concluded], p. 49–63. (März.)

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Liese, C. Nochmals "Irrlichter." p. 71–72. (März.)

Gockel, A[lbert]. Zur Gewittervorhersage. p. 73–75. (April.) [Forecasting thunder storms from observations of atmospheric-electric conductivity and potential gradient.]

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Schmidt, Wilhelm. Uber den Windeinfluss bei Niederschlagsmessungen. p. 108–109. (Mai.)

Rudel, K[aspar]. Sankt Kunigund—bringt d'Wärm' von unt'. p. 110–111. (Mai.)

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Schmidt, Wilhelm. Abnorme Hörbarkeit und Wasserstoffsphäre. p. 145–149. (Juli.)

Göschl, Franz. Regelmässige Hochdruckverschiebungen als Grundlage für eine Wettervorhersage auf längere Zeiträume. p. 149–152. (Juli.)

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Meissner, Otto. Bemerkenswerte Witterungsereignisse der letzten Jahre. (1908–1914.) [Continuation.] p. 215–216. (Sept.)

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Göschl, Franz. Nachweis von Hochdruckwanderungen aus Tabellen über Maximum-Typen. p. 242–246. (Nov.)

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Maurer, J[ulius]. Ein neues Glied der meteorologischen Optik. p. 275–281. (Dez.) [Account of the quasi-permanent glow around the sun and its variations. [Cf. Mo. Weather Rev. Dec., 1917. p. 577.]

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Hergesell, H[ugo]. Die Windverhältnisse in den unteren Luftschichten über Strassburg nach langjährigen Messungen in verschiedenen Höhenlagen. p. 309. [Shows diurnal march of wind velocity at various levels up to 140 meters.]

König, Walter. Zyklonen und Kreiseltheorie. p. 9–14.

Schmidt, Wilhelm. Folgerungen aus der Böenforschung für die Luftschiffahrt. p. 14–19.

Wegener, Kurt. Meteorologie und Flugkunst. p. 19–24.

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Süring, R[einhard]. Absteigende Luftströmungen auf Bergen. p. 26–29.

Schubert, J[ohannes]. Die Einwirkungen des grünen Buchenwaldes auf die Temperatur und Feuchtigkeit der Luft. p. 29–32.

Weber, L[eonhard]. Temperaturgleichungen in Kiel. p. 32–36.

Heilmann, G[ustav]. Meeresströmungen und Gewitterhäufigkeit. p. 36–39.

Maurer, J[ulius]. Die Niederschlagsmessung im Hochgebirge. p. 39–43.

Kassner, C[arl]. Die Verteilung der grössten Niederschläge in der Provinz Brandenburg. p. 43–47.

Lindemann, C[arl]. Mittlere Niederschlagsmengen in 50 Flussgebieten des Königreiches Sachsen. 1899–1913. p. 48–52.

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Wegener, Alfred. Über den Farbenwechsel der Meteore. p. 62–66.

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Freybe, O[tto.] Wettertafeln. p. 98–102. [Gives rules for frost prediction at Cassel from weather map.]

Rudel, K[aspar.] Wetterregeln und Kalenderreform. p. 102–104.

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Pinkhof, M. Samengestelde halo op 7 october 1918. p. 129–131. [Descr. of halo which included the arcs of Lowitz.]

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Van Dijk, G. Noorderlicht in de avonden van 25 december 1918, 3 en 4 januari 1919. p. 138–140.

SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING FEBRUARY, 1919.

By HERBERT H. KIMBALL, Professor in Charge.

[Dated: Solar Radiation Investigations Section, March 31, 1919.]

For a description of instrumental exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, **47**:4.

The monthly means and departures from normal in Table 1 show that solar and sky radiation intensities averaged close to normal at all three stations. At Lincoln, however, there were few days when the sky was clear. At Washington, a noon reading of 1.50 calories per minute per square centimeter on February 19 is as high as any solar radiation intensity ever measured at Washington in February.

On the afternoon of the 19th, with the sun at zenith distance 79° to 80°, and thin bands of cirrus clouds in the vicinity of the sun, unusually high intensities were measured. They indicate a higher atmospheric transmission coefficient than do readings obtained 20 minutes earlier, with the sun at zenith distance 76°, and the sky clear. A similar increase in radiation intensities has been noted on previous occasions with thin cirrus clouds near the sun. Since the pyrheliometer receives heat from a circular area of the sky the diameter of which subtends an angle of 16°, it seems probable that the cirrus bands must have been slightly to one side of the sun, and reflected sunlight into the tubular opening of the pyrheliometer, without intercepting appreciably the direct solar rays.

Table 3 shows a normal amount of radiation at Washington, and a deficiency at Lincoln and Madison, amounting to 14 per cent of the normal radiation for February at the respective stations.

Skylight polarization measurements made on six days at Washington give a mean of 53 per cent with a maximum of 65 per cent on the 19th. At Madison, measurements obtained on five days during the first half of the month, when the ground was free from snow, give a mean of 66 per cent, with a maximum of 68 per cent on the 7th.

TABLE 1.—*Solar radiation intensities during February, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

WASHINGTON, D. C.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Feb. 1	(*1.46)		1.29	1.20	1.11	1.01	0.93	0.87	0.82	0.73
6			1.09	0.92	0.74	0.64	0.56	0.49		
7	(*1.40)	1.25	1.09	0.96	0.83	0.73				
10					1.20					
11			1.18	1.03	0.93	0.81	0.73	0.68	0.64	
14					0.99					
18				0.99	0.95	0.92				
19	(*1.60)	1.50	1.36	1.26	1.19	1.14	1.08	1.00	0.95	
26		1.30	1.18	1.08	0.93	0.85	0.78			
27	(*1.31)	1.23	1.12	1.03	0.94					
Monthly means		1.32	1.19	1.06	0.98	0.87	0.82	0.76	0.80	(0.73)

* Extrapolated, and reduced to mean solar distance.

TABLE 1.—*Solar radiation intensities during February, 1919*—Continued.

WASHINGTON, D. C.—Continued.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Departure from 11-year normal		−0.06	−0.02	−0.05	−0.04	−0.07	−0.03	−0.06	+0.02	−0.06
P. M.										
Feb. 1			1.26	1.21	1.16	1.04	1.00	0.95	0.91	0.87
19			1.36	1.25	1.16	1.10	1.05	1.03	1.01	0.99
24			1.20							
26			1.18	0.98	0.83	0.72	0.63	0.54		
Monthly means			1.23	1.15	1.05	0.95	0.89	0.84	(0.96)	(0.93)
Departure from 11-year normal			+0.03	+0.04	+0.04	+0.04	+0.04	+0.03	+0.20	+0.19

MADISON, WIS.

A. M.										
Feb. 4			1.43	1.33	1.23	1.15	1.09	1.04	0.99	0.94
5	(*1.50)		1.46	1.40	1.31	1.24	1.19	1.12	1.06	0.99
8			1.38							
17			1.36							
18	(*1.55)		1.43	1.37	1.29	1.22	1.16	1.10	1.03	0.99
25	(*1.65)		1.50	1.40						
Monthly means			1.43	1.38	1.28	1.20	1.15	1.09	1.03	0.97
Departure from 9-year normal			+0.04	+0.06	+0.04	±0.00	±0.00	+0.06	+0.10	+0.01
P. M.										
Feb. 4			1.39	1.30	1.20	1.10				
5			1.46	1.29	1.18	1.08				
6			1.35	1.28	1.20					
7			1.37	1.28	1.23					
11			1.25	1.13	1.02					
15				1.28						
17			1.38	1.32	1.27					
25			1.50	1.37	1.34					
Monthly means			1.39	1.28	1.21	(1.09)				
Departure from 9-year normal			−0.01	−0.03	±0.00	−0.04				

LINCOLN, NEBR.

A. M.										
Feb. 8					0.97	0.85				
25		1.50	1.44							
Monthly means		(1.50)	(1.44)		(0.97)	(0.85)				
Departure from 4-year normal		+0.05	+0.01		−0.26	−0.28				
P. M.										
Feb. 3						1.08	1.00			
11			1.36	1.29	1.22	1.17	1.11	1.05	0.98	
25			1.31	1.15		0.88			0.60	
Monthly means			(1.34)	(1.22)	(1.22)	1.04	(1.06)	(1.05)	(0.79)	
Departures from 4-year normal			−0.04	−0.08	−0.05	−0.10	−0.02	−0.03	−0.14	

* Extrapolated, and reduced to mean solar distance.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.		
Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.
1919.	mm.	mm.	1919.	mm.	mm.	1919.	mm.	mm.
Feb. 1..	2.74	2.26	Feb. 4.	1.12	1.02	Feb. 3.	2.06	2.49
6..	1.96	2.62	5.	0.91	1.02	8.	1.60	1.88
7..	2.36	2.74	6.	1.07	1.32	11.	3.99	5.16
10..	2.49	2.06	7.	0.79	1.07	25.	0.91	1.88
11..	2.26	2.26	8.	1.07	1.68	.....	.....	.....
14..	7.57	7.37	11.	3.00	4.17	.....	.....	.....
18..	2.26	3.00	15.	2.87	2.62	.....	.....	.....
19..	1.96	2.49	17.	3.15	2.26	.....	.....	.....
24..	3.30	3.99	18.	1.68	2.13	.....	.....	.....
26..	1.96	1.96	25.	0.86	0.74	.....	.....	.....
27..	2.74	3.81	.....	.....	.....	.....	.....	.....

TABLE 3.—*Daily totals and departures of solar and sky radiation during February, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Feb. 1	311	206	135	102	− 4	−129	102	− 4	− 129
2	329	127	71	117	− 85	−194	219	− 89	− 323
3	259	41	301	45	−173	34	264	−262	− 289
4	49	282	268	−168	66	0	96	−196	− 289
5	316	287	194	97	69	− 76	193	−127	− 365
6	288	271	80	66	50	−193	259	− 77	− 558
7	294	293	256	68	69	− 20	327	− 8	− 578
8	209	259	356	− 20	32	77	307	24	− 501
9	316	266	388	83	36	106	390	60	− 395
10	219	183	300	− 17	− 50	14	373	10	− 381
11	298	262	360	58	25	71	431	35	− 310
12	226	274	195	− 17	34	− 97	414	69	− 407
13	78	16	43	−169	−227	−252	245	−158	− 659
14	278	58	227	28	−188	− 71	273	−346	− 730
15	172	236	267	− 82	− 13	− 34	191	−359	− 764
16	335	336	380	78	85	77	269	−274	− 687
17	246	332	170	− 13	78	−136	256	−196	− 823
18	280	340	381	18	84	73	274	−112	− 750
19	405	251	253	141	− 7	− 58	415	−119	− 808
20	331	101	100	64	−160	−213	479	−279	−1,021
Decade departure							**106**	**−289**	**− 640**
21	52	90	336	−217	−173	20	262	−452	−1,001
22	45	75	374	−227	−190	56	35	−642	− 945
23	274	345	456	0	77	135	35	−565	− 810
24	378	169	116	101	−101	−207	136	−666	−1,017
25	69	386	486	−210	114	160	− 74	−552	− 857
26	412	253	147	130	− 23	−183	56	−575	−1,040
27	408	143	102	123	−137	−232	179	−712	−1,272
28	140	44	456	−148	−240	118	31	−952	−1,154
Decade departure							**−448**	**−673**	**−133**
Excess or deficiency since first of year						gr.-cal.	**204**	**−1,364**	**−586**
						per cent.	**1.6**	**−11.2**	**−3.9**

HALO PHENOMENA OBSERVED DURING FEBRUARY, 1919.

By WILLIS RAY GREGG, Meteorologist.

Station.	Altitude.	Latitude.	Longitude.	Date.	Form observed.	Time of—		Theodolite readings.					
						Beginning.	Ending.	Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m.	° ′	° ′						°	°	°	°	°
Broken Arrow, Okla.*	233	36 02	95 49	4	Solar halo, 22°	12:45 p. m.		2:20 p. m.	22	23.5	360		32
				6	Solar halo, 22°	8:45 a. m.	3:30 p. m.				270		
				12	Lunar halo, 22°	8:20 p. m.	D. N.						
				28	Solar halo, 22°	7:45 a. m.	8:10 a. m.	7:55 a. m.	21.5	22.6	20		12.1
				28	Parhelion, right, 22°	7:45 a. m.	8:10 a. m.	7:55 a. m.				22	
				28	Parhelion, left, 22°	7:45 a. m.	8:10 a. m.	7:55 a. m.				22	
Canton, N. Y.	137	44 36	75 10	10	Lunar halo, 22°	9:00 p. m.	10:25 p. m.						
				11	Lunar halo, 22°	9:20 p. m.	11:00 p. m.						
				11	Paraselene, right, 23°	9:20 p. m.	10:00 p. m.						
				11	Lunar halo, 46°	9:50 p. m.	10:03 p. m.						
				13	Solar halo, 22°	2:10 p. m.	3:00 p. m.						
				17	Solar halo, 22°	2:12 p. m.	2:35 p. m.						
				18	Solar halo, 22°	8:25 a. m.	9:10 a. m.						
				27	Light pillar	5:21 p. m.	5:42 p. m.						
				27	Solar halo, 16°	5:20 p. m.	5:40 p. m.						
				28	Solar halo, 22°	2:10 p. m.	3:05 p. m.						
Cincinnati, Ohio.	191	39 06	84 30	7	Upper tangent arcs	10:05 a. m.	3:10 p. m.						
				8	Solar halo, 22°	11:35 a. m.	12:30 p. m.						
				8	Lunar halo, 22°	5:50 p. m.	9:15 p. m.						
				11	Lunar halo, 22°	8:25 p. m.	8:40 p. m.						
				24	Solar halo, 22°	10:55 a. m.	11:50 a. m.						
Dayton, Ohio.	274	39 46	84 10	2	Solar halo, 22°	8:05 a. m.	3:20 p. m.						
				7	Solar halo, 22°	12:58 p. m.	1:15 p. m.						
				8	Solar halo, 22°	3:10 p. m.	3:45 p. m.						
				8	Lunar halo, 22°	5:50 p. m.	D. N. p.						
				12	Lunar halo, 22°	8:30 p. m.	9:00 p. m.						
Drexel, Nebr.*	396	41 20	96 16	7	Solar halo, 22°	4:50 p. m.	4:58 p. m.	4:55 p. m.	21.5	22.5	5		10
				7	Lunar halo, 22°	7:10 p. m.	7:45 p. m.	7:15 p. m.	22	23	360		66
				11	Lunar halo, 22°	10:50 p. m.	11:08 p. m.	11:06 p. m.	22	22.5	360		64
				12	Solar halo, 22°	11:40 a. m.	12:24 p. m.	12:15 p. m.	22	22.5	300		34
				15	Solar halo, 22°	12:25 p. m.	4:30 p. m.	1:41 p. m.	22	22.5	180		33
				15	Upper tangent arc	3:08 p. m.	3:30 p. m.	3:14 p. m.			10	22.5	24
				19	Solar halo, 22°	10:13 a. m.	10:30 a. m.	10:20 a. m.	21.5	22.5	200		28
				28	Solar halo, 22°	8:10 a. m.	10:25 a. m.	9:05 a. m.	22	22.5	360		20
				28	Parhelion, right, 22°	8:10 a. m.	9:30 a. m.	9:05 a. m.			3	23	20
				28	Parhelion, left, 22°	8:10 a. m.	9:30 a. m.	9:05 a. m.			3	23	20
				28	Circumzenithal arc	8:10 a. m.	9:30 a. m.	9:05 a. m.			12	46	20
Ellendale, N. Dak.*	444	45 59	98 34	8	Lunar halo, 22°	7:20 p. m.	D. N.						
				9	Lunar halo, 22°	7:15 p. m.	D. N.						
				15	Solar halo, 22°	8:25 a. m.	2:30 p. m.	8:58 a. m.	22.5	23	220		12
				16	Solar halo, 22°	10:20 a. m.	12:15 p. m.						
				25	Parhelion, right, 22°	4:10 p. m.	6:15 p. m.						
				25	Parhelion, left, 22°	4:10 p. m.	6:15 p. m.						
Grossbeck, Tex.*	141	31 30	96 28	15	Solar halo, 22°	12:10 p. m.	4:00 p. m.	1:10 p. m.	22	24.5	360		45.5
				18	Solar halo, 22°	3:50 p. m.	4:00 p. m.	3:55 p. m.	22	25.5	30		26
				23	Solar halo, 22°	1:45 p. m.	3:18 p. m.	1:48 p. m.	23	26	180		44
Leesburg, Ga.*	85	31 47	84 14	1	Solar halo, 22°	6:59 a. m.	12:00 m.	11:00 a. m.	22		360		
				8	Solar halo, 22°	2:00 p. m.	2:15 p. m.	2:10 p. m.	22		10		
				10	Solar halo, 22°	3:25 p. m.	4:40 p. m.	4:10 p. m.	22		300		
				10	Lunar halo, 22°	5:51 p. m.	10:15 p. m.	6:45 p. m.	22		360		
				12	Solar halo, 22°	11:06 a. m.	11:27 a. m.	11:17 a. m.	22		165		
				12	Solar halo, 22°	3:45 p. m.	4:02 p. m.	3:53 p. m.	22		10		
				12	Parhelian, right, 22°	3:45 p. m.	4:02 p. m.	3:53 p. m.				22	16
				12	Parhelian, left, 22°	3:45 p. m.	4:02 p. m.	3:53 p. m.				22	16
				12	Parhelic circle	3:45 p. m.	4:02 p. m.	3:53 p. m.			17		16
				16	Solar halo, 22°	12:23 p. m.	12:36 p. m.	12:26 p. m.	22		20		
				19	Solar halo, 22°	11:20 a. m.	2:54 p. m.	2:25 p. m.	22		300		
				24	Solar halo, 22°	12:30 p. m.	12:45 p. m.	12:32 p. m.	22		75		
				28	Solar halo, 22°	1:32 p. m.	1:56 p. m.	1:47 p. m.	22		148		
Madison, Wis.	297	43 05	89 23	2	Solar halo, 22°	8:00 a. m.	1:00 p. m.						
				5	Solar halo, 22°	4:00 p. m.	Sunset.						
				5	Parhelion, right, 22°	3:48 p. m.	Sunset.						
				5	Upper tangent arc	4:00 p. m.	Sunset.						
				6	Solar halo, 22°	8:40 a. m.	8:50 a. m.						
				6	Parhelion, right, 22°	8:40 a. m.	8:50 a. m.						
				6	Parhelion, left, 22°	8:40 a. m.	8:50 a. m.						
				6	Upper tangent arc	8:40 a. m.	8:45 a. m.						
				6	Solar halo, 46°	8:35 a. m.	8:40 a. m.						
				7	Solar halo, 22°	10:45 a. m.	11:00 a. m.						
				7	Parhelion, right, 22°	4:15 p. m.	Sunset.						
				7	Upper tangent arc	4:15 p. m.	Sunset.						
				8	Lunar halo, 22°	6:20 p. m.	9:00 p. m.						
				11	Solar halo, 22°	12:20 p. m.	12:30 p. m.						
				12	Lunar halo, 22°	6:40 p. m.	8:45 p. m.						
				15	Solar halo, 22°	11:40 a. m.	1:40 p. m.						
				16	Lunar halo, 22°	8:45 p. m.	10:30 p. m.						
				19	Solar halo, 22°	10:30 a. m.							
				23	Solar halo, 22°	1:50 p. m.	2:15 p. m.						
				24	Solar halo, 22°	8:10 a. m.							
				26	Solar halo, 22°	9:30 a. m.							
Nashville, Tenn.	166	36 10	86 47	10	Lunar halo, 22°			7:30 p. m.					
Royal Center, Ind.*	225	40 53	86 29	2	Solar halo, 22°	7:30 a. m.	2:00 p. m.	8:40 a. m.	22.3	23.3	225		16.2
				2	Upper tangent arc	8:00 a. m.	2:00 p. m.	8:40 a. m.			60	22	16.2
				2	Solar halo, 46°	8:50 a. m.	11:05 a. m.	9:11 a. m.	46	47	180		18
				10	Solar halo, 22°	12:40 p. m.	1:40 p. m.	12:30 p. m.			270		
				12	Solar halo, 22°	9:15 a. m.	4:05 p. m.	9:30 a. m.			360		
				24	Solar halo, 22°	8:35 a. m.	3:15 p. m.	8:36 a. m.			180		
				25	Solar halo, 7°	1:55 p. m.	2:02 p. m.	2:00 p. m.	5	9	120		
				26	Solar halo, 22°	10:14 a. m.	1:20 p. m.	1:15 p. m.	22	23	180		37.5
				26	Parhelic circle	10:14 a. m.	10:18 a. m.	10:14 a. m.			150		
				27	Solar halo, 22°	10:15 a. m.	12:15 p. m.	11:50 a. m.	22.5	24.3	360		41.8

* Aerological station.

Halo Phenomena Observed During February, 1919—Continued.

Station.	Altitude.	Latitude.	Longitude.	Date.	Form observed.	Time of— Beginning.	Time of— Ending.	Theodolite readings. Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m.	° ′	° ′						°	°	°	°	°
Tatoosh Island, Wash.	26	48 23	124 44	5	Solar halo, 22°	1:05 p. m.	2:40 p. m.						
				5	Parhelion, right, 22°	2:09 p. m.	2:11 p. m.						
				5	Parhelion, left, 22°	2:18 p. m.	2:19 p. m.						
				5	Lunar halo, 22°	7:30 p. m.	7:35 p. m.						
				6	Solar halo, 22°	9:55 a. m.	11:10 a. m.						
				6	Lunar halo, 22°	7:35 p. m.							
				7	Solar halo, 22°	10:00 a. m.	4:25 p. m.						
				9	Solar halo, 22°	3:58 p. m.	4:05 p. m.						
				13	Solar halo, 22°	10:42 a. m.	3:20 p. m.						
				13	Parhelion, left, 22°	11:06 a. m.	11:10 a. m.						
				16	Solar halo, 22°	12:03 p. m.	4:30 p. m.						
				17	Lunar halo, 22°	D. N. a.	6:25 a. m.						
				17	Solar halo, 22°	5:05 p. m.	5:06 p. m.						
				18	Solar halo, 22°	9:44 a. m.	10:25 a. m.						
				18	Solar halo, 46°	9:50 a. m.	10:20 a. m.						
				19	Solar halo, 22°	11:50 a. m.	2:44 p. m.						
				21	Lunar halo, 22°	D. N. a.	5:26 a. m.						
				26	Solar halo, 22°	2:29 p. m.	2:46 p. m.						
				28	Solar halo, 22°	12:12 p. m.	1:28 p. m.						
				28	Parhelion, left, 22°	12:48 p. m.	12:55 p. m.						
				28	Upper tangent arc	12:33 p. m.	1:27 p. m.						
York, N. Y.	232	42 52	77 53	7	Lunar halo	7:00 p. m.	10:15 p. m.	8:00 p. m.	23	29	360		56.3
				7				8:05 p. m.		28	360		57
				7				8:15 p. m.	23	31	360		55
				7				8:25 p. m.	22		360		53
				11	Solar halo, 22°	10:30 a. m.	12:30 p. m.				360		
				11	Lunar halo, 22°	6:15 p. m.	7:50 p. m.				360		
				13	Solar halo, 22°	12:30 p. m.	1:30 p. m.				30		
				19	Lunar halo, 22°		6:45 a. m.						
				20	Solar halo, 22°	4:30 p. m.	5:15 p. m.				360		
				24	Solar halo, 22°	3:30 p. m.	4:30 p. m.				360		
				28	Solar halo, 22°	10:20 a. m.	11:30 a. m.				360		

Station.	Date.	Colors.†	Degree of brightness.	Clouds. Amount.	Clouds. Kind.	Clouds. Direction.	Station pressure.	Precipitation. Last previous ended.	Precipitation. First subsequent began.
Broken Arrow, Okla.*	4	Y	Bright	8	Ci. st.	sw.	Stationary	D. N. p., 2d.	D. N. a., 8th.
	6	Y	Dim	8	Ci. st.	w.	Stationary	D. N. p., 2d.	D. N. a., 8th.
	12	Y	Dim	Few	Ci. st.	s.	Falling	4:30 p. m., 12th.	D. N. a., 13th.
				9	St.	s.			
	28	R, Y	Bright	7	St. cu.	wnw.	Rising	7:10 a. m., 28th.	8:05 a. m., 28th
	28								
	28								
Canton, N. Y.	10	O	Dim	2	Ci. st.	w.	Stationary	D. N. a., 9th.	D. N. a., 14th.
	11	O	Brilliant	4	Ci. st.	w.	Falling	D. N. a., 9th.	D. N. a., 14th.
	11								
	11								
	13	O	Dim	2	Ci. st.	w.	Falling	D. N. a., 9th.	D. N. a., 14th
	17	O	Dim	1	Ci. st.	w.	Falling	3:35 p. m., 16th.	2:23 p. m., 21st.
	18	R	Bright	3	Ci. st.	w.	Rising	3:35 p. m., 16th.	2:23 p. m., 21st.
	27			1	Ci.	w.	Stationary	1:22 p. m., 26th.	D. N. a., 28th.
				1	Ci. st.	w.			
	27	R, O, G	Bright	2	A. st.	w.			
				1	St.	e.			
	28	O	Dim	2	Ci. st.	w.	Falling	D. N. a., 28th.	
Cincinnati, Ohio	7	R, O, Y, G, B, V	Bright	10	A. st.	sw.	Falling	D. N. a., 4th.	5:55 a. m., 9th.
	8	R, O, Y	Dim	9	Ci. st.	w.	Falling	D. N. a., 4th.	5:55 a. m., 9th.
	8		Bright	10	A. st.	w.	Stationary		
	11		Dim	7	Ci. st.	nw.	Falling	5:00 p. m., 11th.	4:00 a. m., 14th.
	24	R, O, Y, G	Dim	10	A. st.	w.	Falling	11:30 a. m., 22d.	5:45 a. m., 25th.
Dayton, Ohio	2		Dim	6	Ci. st.	nw.	Falling	12:45 p. m., 23d.	7:15 a. m., 3d.
	7		Dim	10	Ci. st.	w.	Falling	6:30 a. m., 4th.	6:05 p. m., 7th.
	8		Dim	7	Ci. st.	w.	Stationary	D. N. p., 7th.	D. N. a., 9th.
	8	R	Bright	10	Ci. st.	w.	Stationary	D. N. p., 7th.	D. N. a., 9th.
	12		Dim	10	Ci. st.	sw.	Falling	7:08 p. m., 12th.	D. N. a., 13th.
Drexel, Nebr.*	7	O. W	Bright	2	Ci. st.	wnw.	Stationary	2:28 p. m., 6th.	10:42 a. m., 8th.
	7	W	Dim	4	A. st.	w.	Rising		
				6	A. cu.	w.			
	11	W	Dim	2	Ci. st.	w.	Stationary	8:15 p. m., 10th.	7:40 p. m., 12th.
	12	R, O, Y, G, B	Dim	7	Ci. st.	sw.	Falling	8:15 p. m., 10th.	7:40 p. m., 12th.
	15	O, Y, G, B	Dim	7	Ci. st.	n.	Rising	12:20 p. m., 15th.	5:15 a. m., 20th.
	15	O, B	Dim	3	St.	nnw.			
	19	W	Dim	4	Ci. st.	wsw	Falling	12:20 p. m., 15th.	5:15 a. m., 20th.
				3	A. cu.	ssw.			
	28	R, O, Y, G, B	Bright	2	Ci.	wsw.	Rising	7:15 a. m., 28th.	5:45 p. m., 3d.
				6	st.	nnw.			
	28	W	Dim						
	28	W	Dim						
	28	R, O, Y, G							
Ellendale, N. Dak.*	8	R	Bright				Falling	9:10 a. m., 7th.	D. N. a., 13th.
	9	R	Bright				Falling	9:10 a. m., 7th.	D. N. a., 13th.
	15	R	Bright	9	Ci. st.	nw.	Rising	3:30 p. m., 14th.	9:28 a. m., 17th.
	16	R	Dim	10	Ci. st.	w.	Stationary	3:30 p. m., 14th.	9:28 a. m., 17th.
	25	R	Bright	10	Ci. st.	nw.	Stationary	1:35 p. m., 24th.	D. N. a., 27th.
	25	R	Bright						
Groesbeck, Tex.*	15	R, O, Y, G, B	Bright	6	Ci. st.	nw.	Stationary	7:06 p. m., 12th.	D. N. a., 17th.
	18	R, Y, B	Dim	6	Ci. st.	w.	Falling	D. N. a., 18th.	12:10 p. m., 19th
	23	R, Y, G, B	Dim	7	Ci. st.	wsw.	Falling	D. N. p., 21st.	1:28 p. m., 24th.

* Aerological station.

† Beginning with part nearest sun or moon: R, red; O, orange; etc.

Halo Phenomena Observed During February, 1919—Continued.

Station.	Date.	Colors.	Degree of brightness.	Clouds.			Station pressure.	Precipitation.	
				Amount.	Kind.	Direction.		Last previous ended.	First subsequent began.
Leesburg, Ga.*	1	R	Dim	6	Ci. st	w.	Falling	D. N. a., 26th	5:20 p. m., 2d.
	8	R	Dim	Few.	Ci. st	w.	Stationary	7:20 p. m., 5th	6:02 a. m., 9th.
	10	R	Dim	9	Ci. st	nw.	Stationary	10:21 a. m., 9th	12:18 p. m., 11th.
	10	R	Dim	8	Ci. st	nw.	Rising		
	12	R, O, Y	Dim	8	Ci	nw.	Falling	4:50 p.m., 11th	D. N. a., 13th.
	12		Dim	3	Ci. st	sw.	Falling		
	12	R, O, Y, G, B	Bright	2	A. cu	w.			
	12	R, O, Y, G, B	Bright	2	Cu	ssw.			
	12	W	Bright						
	16			2	Ci. st	sw.	Falling	4:30 p. m., 13th	3:55 p. m., 17th.
	19	R, Y, B	Dim	3	Ci. st	w.	Falling	4:01 p. m., 17th	D.N. a., 20th.
				6	A. cu	w.			
	24	R	Dim	5	Ci. st	w.	Falling	11:15 a. m., 22d	4:15 p. m., 24th.
	28	R, Y, G	Dim	2	Ci. st	sw.	Falling	5:36 a. m., 28th	2:50 p. m., 28th.
				7	St. cu	s.			
Madison, Wis	2	R	Bright	10	Ci. st	sw.	Falling	3:00 p. m., 18th	10:05 a. m., 3d.
	5			2	Ci. st	w.	Stationary	D. N., p., 3d	9:00 a. m., 8th.
	5	W	Dim						
	6		Dim	Few.	Ci. st	nw.	Stationary	D. N. p., 3d	9:00 a. m., 8th.
	6		Bright						
	6		Bright						
	6		Bright						
	6		Dim						
	7	W	Dim	3	Ci. st	sw.	Stationary	D. N. p., 3d	9:00 a. m., 8th.
	7	R, O, Y	Brilliant	Few.	Ci. st	w.			
	7	R	Bright						
	8	W	Bright	9	Ci. st	nw.	Stationary	9:45 a. m., 8th	6:30 a. m., 9th.
	11	W	Dim	1	Ci. st	w.	Falling	10:00 a. m., 9th	D. N. a., 13th.
	12	W	Bright	3	Ci. st	w.	Stationary	10:00 a. m., 9th	D. N. a., 13th.
	15	R	Bright	4	Ci. st	w.	Rising	D. N. p., 14th	4:20 a. m., 20th.
	16	W	Bright	6	Ci. st	w.	Stationary	D. N. p., 14th	4:20 a. m., 20th.
	19	W	Dim	8	Ci. st	w.	Stationary	D. N. p., 14th	4:20 a. m., 20th.
	23	W	Dim	1	Ci. st	w.	Rising	D. N. p., 22d	3:45 p. m., 24th.
	24	W	Dim	10	Ci. st	w.	Falling	D. N. p., 22d	3:45 p. m., 24th.
	26	W	Dim	10	Ci. st	w.	Stationary	Snowing	
Nashville, Tenn	10		Dim	4	Ci. st		Falling	8:40 p. m., 9th	D. N. a., 11th.
Royal Center, Ind.*	2	R, O, Y, G, B	Bright	10	Ci. st	w.	Stationary	7:15 a. m., 23d	7:18 a. m., 3d.
	2		Dim						
	2	R, O, Y, G, B	Dim						
	10	R	Dim	3	Ci. st	nw.	Falling	5:00 p. m., 9th	9:50 a. m., 11th.
				5	A. cu	nw.			
	12	R	Dim	6	Ci	w.	Stationary	11:05 a. m., 11th	D. N. a., 13th.
	24	R	Dim	7	Ci. st	sw.	Falling	5:55 p. m., 22d	3:00 a. m., 25th.
	25	R, O, Y, G, B	Brilliant	3	Ci. cu	w.	Rising	9:15 a. m., 25th	10:25 a. m., 28th.
	26	R, B	Dim	10	Ci. st	nw.	Falling	9:15 a. m., 25th	10:25 a. m., 28th.
	26	W	Bright	4	Ci. st	nw.	Rising		
	27	R, O, Y, G, B	Dim	8	Ci. st	w.	Falling	9:15 a. m., 25th	10:25 a. m., 28th.
Tatoosh Island, Wash	5	O, Y, B	Dim	6	Ci. st	nw.			
	5	R, O, Y, B	Bright	1	Cu	w.	Rising	3:20 p. m., 4th	3:41 p. m., 5th.
	5	R, O, Y, B, V	Dim						
	5	W	Dim	1	Ci. st		Rising	4:20 p. m., 5th	D. N. p., 5th.
	6	O	Dim	7	A. st	e.	Falling	P. N. a., 6th	D. N. p., 7th.
	6	W	Dim	7	Ci. st		Rising		
	7	R, O, G	Dim	9	A. st	w.	Falling	D. N. a., 6th	D. N. p., 7th.
	9	O	Dim	7	A. st	sw.	Falling	2:50 p. m., 9th	4:06 p. m., 9th.
	13	R, O	Bright	1	Ci	nw.			
	13	W	Dim	3	St. cu	s.	Falling	D. N. a., 13th	D. N. p., 13th.
	16	R, O, Y, G, B	Bright	7	Ci. st	s.	Rising	10:15 a. m., 16th	7:58 p. m 18th.
				2	St. cu	sw.			
	17	O	Dim	4	Ci. st	s.	Rising	10:15 a. m., 16th	7:58 p. m., 18th.
	17	R, B	Dim	Few.	Ci	nw.	Rising		
	18	O	Dim	Few.	Ci. st		Rising	10:15 a. m., 16th	7:58 p. m., 18th.
				9	St. cu	sw.			
	19	O	Dim	8	A. st		Falling	11:50 a. m., 19th	D. N. p., 21st.
				2	St. cu	e.			
	21	W	Dim	1	Ci. st	nw.	Falling	11:50 a. m., 19th	D. N. p., 21st.
				1	St. cu	e.			
	26	W	Dim	6	A. cu	nw.	Rising	9:50 a. m., 26th	D. N. a., 27th.
	28	R, Y, B	Dim	3	Ci. st	nw.			
	28	W	Dim	6	St. cu	w.	Rising	D. N. a., 28th	7:21 p. m., 28th.
	28	R, O, Y, G, B, V	Brilliant						
York, N. Y.	7	W	Brilliant	3	Ci. st	w.	Stationary	D. N. p., 6th	4:00 a. m., 8th.
	7	W	Brilliant						
	7	W	Brilliant						
	7	W	Dim						
	11	R	Bright	3	Ci. st	w.	Falling	3:00 p. m., 10th	D. N. p., 11th.
	11	W	Bright	4	Ci. cu	w.			
	13	O	Dim	2	Ci. st	w.	Falling	D. N. p., 11th	7:15 p. m., 13th.
				8	Ci. cu	w.			
	19	W	Bright		Ci. st		Rising	9:30 a. m., 18th	D. N. p., 20th.
	20	R	Dim	10	Ci. st	w.	Stationary	9:30 a. m., 18th	D. N. p., 20th.
	24	R	Bright	2	Ci	wnw.	Rising	2:00 p. m., 23d	1:00 p. m., 25th.
	28	R	Brilliant	8	Ci. st	sw.	Falling	2:00 p. m., 27th	9:00 p. m., 28th.
				2	St. cu	s.			

* Aerological station.

† Beginning with part nearest sun or moon: R, red; O, orange, etc.

NOTES.

A very unusual and interesting halo was observed at Canton, N. Y., on February 27, 1919. Mr. J. S. Hazen, Observer, states that "this phenomenon was studied carefully and measurements were made as accurately as possible by means of a nephoscope. The colors were vivid, especially the green, which was a bright light green; the red and orange were less brilliant. The clouds consisted of an approaching bank of A. St. low down on the horizon, with some Ci. and Ci. St. and some that were classed as 'false' Ci. The 'false' type apparently gave the green color. The colors were arranged as in halos with the red nearest the sun. The width of the halo was between 2° and 3°. The light pillar, which occurred at the same time, was about one-half a degree in width and was colored dull orange merging into red."

The halo, as measured, has a radius of about 16°. Similar occurrences are noted by Besson in "Different Forms of Halos," p. 23. In 1839 a halo of 14° and coincidently one of 16° were seen by Heiden; in 1900 one of 17° was seen by Besson and Duthiel; and in 1899 and 1905 one of 17° 55′ was seen by Hissink, also one of the same radius was later observed by Krčmar.

Attention is called to the halo observed at Royal Center, Ind., on February 25, 1919. Mr. R. E. Frushour, Assistant Observer, states that "this phenomenon became visible as the patch of Ci. Cu. passed over the sun. It was very much like a halo, except that there was no distinct outline, it being wider at some places than at others. The colors were very brilliant and in regular halo order. The red was probably 5° from the sun and the blue probably 9°, although, its duration being so brief, it was impossible to get very accurate readings." Besson notes that a halo of 7°–8° was seen by Arctowski in 1898 and by Hissing in 1899.

Mr. Milroy N. Stewart, Cooperative Observer at York, N. Y., reports concerning the observation on February 7, 1919, that "the elliptical form of this halo was very apparent, even to the unaided eye. The upper and lower arcs for about 45° were much brighter than the sides. There was absolutely no hint of a circular halo with enveloping arcs; only one ring was visible."

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

Normal pressure in the Northern Hemisphere during February as in the preceding month is high over the middle latitudes of the continents and the Atlantic Ocean; 30.60 inches over parts of Siberia, and low over the northern parts of both the Atlantic and Pacific Oceans; about 29.50 inches in the neighborhood of Iceland and over the Aleutian Islands, respectively.

Between the two oceanic areas of low pressure there is a ridge of higher pressure that apparently connects the continental Highs of northeastern Asia and the North American continent by way of Alaska and Bering Sea. The seasonal development of these two great semi-permanent Lows and of the ridge of high pressure between them is responsible for the character of the weather experienced throughout a large portion of the Northern Hemisphere, especially that part north of latitude 40°.

The change in normal pressure from January to February consists in the main of a considerable rise in pressure over the northern part of the Pacific and also, but in a less degree, over the Arctic Ocean and adjacent parts of continental areas bordering thereon. While, therefore, the Aleutian Low begins to fill up during February, the Iceland Low, on the other hand, is intensified slightly and its control of the weather over the North Atlantic extends farther south than in the preceding month. The control of the weather in the Northern Hemisphere is largely bound up with variations, both in the intensity and geographic extent of these centers of high pressure and low pressure, respectively.

In February, 1919, the most conspicuous variation in pressure distribution was a pronounced deficit over Alaska and the Oceanic areas adjacent thereto. Also over the middle and northern portions of the North Atlantic. In general, pressure appears to have been below normal in all parts of the Northern Hemisphere that have thus far been reported upon, save in the Pacific about the Hawaiian Islands.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

Ships' reports thus far received indicate that more bad weather prevailed on the North Pacific Ocean in February than in January, which was a quiet month. Twenty-four ships report gales on one or more days. With a single exception these were on trans-Pacific routes. The gales reported were for the most part encountered north of the 40th parallel. Vessels on the southern route and coastwise shipping experienced favorable weather.

Two fairly well-defined storms appear to have crossed the northern portion of the Pacific during the month, one from about the 3d to 9th, the other from the 10th to 19th. A third storm seemed to be forming in the region near latitude 35° N., longitude 145° E., about the 24th, but reports do not yet indicate the extent of development or the course taken. The storm of the second decade appears to have been the most severe. During the period from the 10th to 19th a considerable number of ships came within its field of influence, mostly in the region lying north of the 40th parallel and between the 145th and 175th meridians, east longitude. Shifting gales, as high as force 11, were experienced, with barometer readings as low as 28.60 inches. There is evidence that this storm did not pursue a steady eastward course, but had a retrograde movement at one time, since, when encountered by the British S. S. *Tamaha*, it appeared to have a westward direction. Following is the report of the observer on the *Tamaha:*

While bound from Osaka to San Francisco, true course N. 69° E., speed 10 knots, and while in latitude 42° 0′ N., longitude 165° 50′ E., we passed through the center of a cyclonic depression, traveling westward. At noon on the 15th the weather was fine and settled. Barometer steady at 30, a gentle breeze blowing from the east, blue sky with detached cumulus and cirrus clouds. During the afternoon watch heavy batches of nimbus and cirrus clouds appeared from the eastward covering the whole sky. The glass commenced to fall rapidly, the wind increased in force, and a heavy swell came away from the east. At 4 p. m. the barometer read 29.58, the wind east, 6, sky heavily overcast and snow falling heavily.

As we approached the center of the storm the wind increased in force and the sea became more and more confused, the glass falling rapidly. Several very severe snow squalls were experienced during the night, the wind blowing in sudden gusts at force 8. At midnight the barometer had reached 28.80, wind east, blowing a whole gale, and a very confused sea. At 2 a. m. the wind suddenly veered round to west, falling to force 4, the barometer at 28.63. It continued to blow lightly from the west until 4 a. m., when it commenced to back round to east again, increasing in force.

At 6 a. m. the barometer reached 28.60, the lowest reading during the disturbance; remaining steady for a brief space of time, it commenced rising as rapidly as it fell at the commencement. The wind continued backing to the north, blowing a whole gale until noon, when it began to decrease to a normal force. The sea assumed a more orderly appearance, shifting around with the wind, settling down into a long heavy northerly swell.

The glass continued to rise rapidly. All day the 17th we had moderate weather, but for the next three days we experienced a strong westerly gale with a huge sea from the same direction.

It was undoubtedly this storm which caused the very low pressure at Dutch Harbor on the 17th, when the barometer read 28.40 inches. The general depression, of which it was a part, was probably related to the low pressure which prevailed on the Pacific coast of the United States during the last days of the month.

A rare phenomenon is reported by E. W. Elliott, observer on the American S. S. *Monmouth*. Mr. Elliott states that on February 13, at 3.30 a. m., ship's time, while in latitude 21° 19′ N., longitude 151° W., with the moon showing through clouds, two rainbows, one over the other, lasting for about 10 minutes, were observed in the southeast part of the sky.

NORTH AMERICA.

By A. J. HENRY, Meteorologist.

In the United States and adjacent parts of Canada and Mexico the month, as a whole, was of the mild type of winter weather, there being an absence of the usual sharp changes to cold weather characteristic of the month.

The present winter, therefore, stands in sharp contrast to that of the preceding year. The obvious explanation seems to be that the ridge of high presure in cold winters that joins the Siberian High to the Continental High of North America was absent and, as has been previously stated, pressure was relatively low over Alaska and the Canadian Northwest.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The atmospheric conditions over the North Atlantic Ocean, for the month under discussion, presented unusual features. While not enough vessel reports were received in time to determine the mean monthly pressure over different sections of the ocean, the observations made at a number of land stations show that in the vicinity of the Azores, Bermuda, and along the American coast from Newfoundland to the Gulf of Mexico, the average pressure was below the normal, the greatest departure occurring at Horta, Azores, where the monthly mean was 29.73 inches, the normal being 30.10. This reversal of the usual conditions was responsible for exceptionally severe weather in the region south of the 40th parallel, while over the northern steamer lanes gales were unusually prevalent, and the "westerlies" that can ordinarily be depended on in that region were replaced, during a large part of the month, by winds from the easterly quadrants.

On February 1 strong southeasterly gales of a maximum force of 65 miles an hour, accompanied by "hail" and snow, prevailed over the region between the 30th meridian and the Irish coast, and on the same date westerly winds of gale force were encountered near the 40th parallel and 60th meridian.

The European disturbance moved rapidly eastward, as on the 2d moderate winds were the rule over the storm area of the day before, the same conditions holding true, for the most part, in the waters adjacent to the American coast. On the 3d moderate gales were reported from a limited area between the 38th meridian and the Azores. From the 4th to the 6th the atmospheric circulation was comparatively stagnant, with light to variable winds prevailing over practically the entire ocean. On the 7th the barometric reading at Horta, Azores, was 29.34 inches, being a fall of over half an inch since the previous day; a few reports were received from vessels in widely scattered sections of the ocean, denoting winds of gale force, although comparatively moderate weather prevailed in the vicinity of the Azores. By the 8th the barometer at Horta had fallen to 28.96 inches, accompanied by southeasterly gales of over 50 miles an hour, while the greater part of the region between that locality and the Bermudas was storm swept, and strong northeasterly gales were also encountered off the Irish coast. The storm center moved about 5 degrees toward the north during the next 24 hours, and on the 9th the greater part of the steamer lanes east of the 30th meridian was swept by moderate to strong gales, while unusually heavy weather for the latitude was also reported south of the Azores. During the next 24 hours there was apparently little change in the position and intensity of the disturbance, except that on the 10th no gales were reported over the eastern section of the ocean south of the 40th parallel, and a second LOW had formed near the Bermudas, which afterwards developed into an unusually severe storm. This disturbance shifted slowly northward, and reached its greatest intensity on the 11th when the center was near latitude 40, longitude 52; northwest winds of hurricane force, accompanied by snow, prevailed, with a minimum barometric reading of 28.80 inches, while the storm area extended fron the 30th to the 45th parallels and from the 45th to the 63d meridians. The eastern LOW of the 10th had moved but slghtly and decreased somewhat in intensity, although practically the entire ocean west of the 20th meridian was swept by gales. By the 12th the western disturbance had drifted slightly northward, and the center was now not far from St. Johns, N. F.; westerly winds of over 50 miles an hour, with "hail" and snow, were still encountered over the area between the 35th and 47th parallels, and the 45th and 60th meridians. During the next 24 hours this LOW moved but slightly and decreased in violence, although a few reports were received showing that on the 13th there were moderate gales over the western portion of the steamer lanes. The disturbance shifted slowly eastward, reaching the European coast on the 18th, when moderate southeast gales were recorded.

On the 17th a fairly well developed LOW was central near latitude 40, longitude 55, and westerly winds of about 40 miles an hour were encountered by a number of vessels between the center and the American coast. Moving slowly eastward, by the 19th, the center had reached a point near latitude 45, longitude 47, where the barometer reading was 28.82 inches, and at the same time there was a HIGH with a crest of 30.40 inches near Hatteras. Westerly gales of from 40 to 50 miles an hour prevailed in the vicinity of the LOW, while the anemometer at New York registered a northwesterly gale of nearly 60 miles an hour, the barometer reading 30.22 inches. On the 20th the center of the LOW was near latitude 45, longitude 38, and the HIGH near Norfolk, Va. Moderate gales with snow occurred off the coast of Newfoundland and vessels in the vicinity of the Bermudas encountered northerly winds of over 40 miles an hour. On the 23d there was a disturbance about half way between the Azores and the Irish coast; easterly winds of 40 miles an hour prevailed in the northern quadrants, while westerly gales of greater velocity were reported a short distance south of the center.

On the 24th a LOW was central near Halifax, N. S., and strong easterly gales with snow swept the south coast of Newfoundland, while westerly winds of somewhat less force were reported from the waters adjacent to the New England coast, practically the same conditions existing also on the 25th.

During the remainder of the month there were no well-defined storm areas, although a number of reports were received from vessels in the western division of the ocean, that encountered moderate gales.

The following is an extract from a very interesting letter received from the commanding officer of the U. S. S. *Charleston:*

1. Forwarded herewith are inclosures descriptive of the storm, apparently an extra-tropical cyclone, of the recurving type, encountered by the U. S. S. *Charleston* on February 10–11, 1919, about 200 miles east of Bermuda in latitude 32–20 N., longitude 60 W.

2. It is noted that the S. S. *Accoma* was abandoned in about latitude 36–30 N., longitude 62–40 W., at noon on February 11, after evidently having encountered the storm herein described. Attention is invited to the fact that from our plotting of the storm track the *Accoma* was nearest the storm center at 6 p. m., February 10.

According to the dates furnished, the *Charleston* was apparently some distance south of the center, during the period from 8 p. m. on the 10th to 2 a. m. on the 11th, when westerly winds of over 70 miles an hour prevailed and waves of from 50 to 60 feet in height did considerable damage to the ship. The lowest barometer 29.19 inches occurred from 8 to 9 p. m. on the 10th, the pressure then rising slowly, and the wind gradually diminishing in force, although moderate northwesterly gales prevailing until noon of February 11.

A letter was also received from the commanding officer of the U. S. S. *Antigone* that referred to the same storm. The *Antigone* was some distance north of the position of the *Charleston*, when the gale was at its height, and therefore nearer the center. Extracts from the letter are as follows:

On February 6, about noon, we passed close to the Azores and shortly after leaving the islands the barometer started to fall and the wind to increase in force from the southwest quadrant. The barometer fell until it reached 29.14 inches at 3 a. m. February 7, the wind blowing with a force of from 8 to 9, with moderate sea. At 4 a. m. the wind suddenly shifted to the northwest, the weather cleared, and the wind moderated to force 4 or 5, gradually backing around to the southwest. Barometer rose only slightly on the 7th.

On February 8 the barometer continued very low, with strong northwesterly winds, and moderated on the 9th, the barometer rising as high as 29.97 on the afternoon of the 9th. After midnight on that date it started to fall rapidly and gave signs of an approaching gale, although the barometer had been steadily low, as shown. There was no accompanying swell, nor was there much wind, which was in the southwest quadrant.

February 10, near midnight, the wind began to increase rapidly, the sea picked up materially, and the barometer fell at the rate of about one-tenth of an inch per hour, the wind coming from the west and southwest quadrants. Between 2 and 3 a. m. on the 11th the blow seemed to be at its height. The sea was very rough, the waves being from 30 to 50 feet in height, and it became necessary to heave to with the wind on the bow, as several lifeboats had been stove in, and it was not advisable to risk shipping a sea, loaded as we were with troops. At 5 a. m. the barometer reached its lowest point, 28.53 inches, then rose slightly and remained practically stationary for two hours, the wind and sea being exceptionally heavy. At 6 p. m. the wind began to haul gradually to the westward, and later the barometer started up slowly, then moved rapidly, rising on the average at a rate of about 0.12 inch per hour up to noon, the wind and sea moderating slightly.

When the effect of the wind from the northwest began to be felt a very disagreeable, choppy cross sea was the result. This condition lasted through February 12, the wind continuing strong from the northwest quarter.

On February 11 intercepted messages were received from the steamships *Mumwood* and *Cape Henry*, which gave the height of the barometer at this position. These positions and barometer readings, together with that of the *Antigone* at the same time, follow:

February 11, 3 hours, 42 minutes G. M. T., S. S. *Mumwood* in latitude 34–14 N., longitude 52–09 W., barometer, 29.47 inches.

February 11, 3 hours, 34 minutes G. M. T., S. S. *Cape Henry* in latitude 36–30 N., longitude 50–00 N., barometer 29.26 inches.

February 11, 3 hours, 49 minutes G. M. T., U. S. S. *Antigone* in latitude 37–21, longitude 53–45, barometer 29.18 inches.

The lowest barometer was experienced by the *Antigone* in latitude 27–15 N., longitude 55 W., 20 hours, 46 minutes G. M. T., barometer 28.53 inches.

It is thought that the center of this storm passed very close to the *Antigone*, and to the northward of us, between 2 and 5 a. m., February 11. During that time the barometer reached the lowest point and the wind blew with hurricane force, seas very high though regular, and all around the ship there was a heavy bank of clouds with continuous lightning. Directly overhead the sky was clear nearly all the time, the stars being clearly seen. In other words, the ship seemed to be in a pocket surrounded by heavy clouds, the limits of the horizon being only a mile or two from the ship, as could be seen during the flashes of lightning.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

BRITISH ISLES.

The predominant character of the weather over the British Isles since the commencement of the year has been rainy and dull * * *. February rainfall was in excess of the average in the south and east of England and deficient elsewhere. The general rainfall expressed as a percentage of the average was: England and Wales, 103; Scotland, 38; Ireland, 69; British Isles, 71. The aggregate duration of bright sunshine * * * has been deficient in all districts of the British Isles except in Ireland and in Scotland north; in the southeast district of England the deficiency amounts to 0.6 hour daily for the first nine weeks [of the year], or, in all, 38 hours. At Kew Observatory the sunshine in February was little more than one-half of the average, and at Cambridge it was less than one-half of the normal. In mid February the weather was cold enough for skating in nearly all districts. The month as a whole was cold, the mean temperature was 35°.6 being 4°.1 below the average, and 2°.2 lower than in January.—From Nature, London, Mar. 13, 1919, pp. 30–31; and Symons's Met'l. Mag., Mar., 1919, p. 21.

DETAILS OF THE WEATHER IN THE UNITED STATES, FEBRUARY, 1919.

CYCLONES AND ANTICYCLONES.

By ALFRED J. HENRY, Meteorologist.

Cyclones.—Eleven cyclones have been plotted on Chart III, distributed according to place of origin or first appearance on the daily weather maps as follows: North Pacific 6, South Pacific 2, and Alberta 3. The North Pacific cyclone which appeared off the Washington coast on the morning of the 10th moved thence southeastward across the Plateau and Rocky Mountain regions, pressure at the center, diminishing until on the morning of the 13th when it reached the low value of 28.90 inches at Kansas City, Mo. At this time the surface air over practically the entire area of the United States east of the Rocky Mountains was in cyclonic circulation about the center of the whirl. As the cyclone moved eastward several minor cyclonic systems developed within the greater primary cyclone. The latter passed off to sea over Newfoundland on the 17th.

Anticyclones.—Although pressure was below normal over Alaska and the Canadian Northwest, 6 HIGHS have been plotted as originating in Alberta, 1 in the Hudson Bay region, and 3 apparently moved into the continent from the Pacific. The HIGHS presented no unusual features.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Dated Weather Bureau, Washington, Apr. 1, 1919.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada and the prevailing direction of the winds for February, 1919, are graphi-

cally shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

February was a month of generally low pressure, but without unusual storm activity, particularly the first half of the month, during which time much clear and pleasant winter weather prevailed. The latter half of the month was more turbulent and several storms of wide extent developed, mostly in the southwest, and moved eastward into the central valleys and southern districts. High pressures moving into the country maintained their eastward courses well to the north, and were frequently accompanied by much milder weather than is usual during a winter month.

The average pressure for the month was below normal in practically all portions of the United States and over the eastern half of Canada as well. In the western Canadian Provinces there was a slight excess in pressure, extending southward into the valley of the Red River of the North. The average pressure was distinctly low over the Rocky Mountain districts and the far northwest, and from the lower Missouri Valley eastward and northeastward to the Atlantic coast, the negative departures becoming unusually large over the Canadian Maritime Provinces.

While the general pressure distribution favored winds with strong northerly components over much of the country from the Missouri and Mississippi Valleys eastward, they were, nevertheless, far warmer than are usually experienced from that direction during a winter month, due in the main to moderate temperatures prevailing over northern districts. The absence of any material snow cover and the generally unfrozen condition of the soil materially assisted in increasing the temperature of these air currents as they moved southward. Over the southern plains the winds were mostly from southerly points, while west of the Rocky Mountains they were mainly from southerly or westerly points.

TEMPERATURE.

At the beginning of the month moderate winter temperatures prevailed in most sections of the country, continuing till about the middle of the first decade, when a sharp fall occurred over eastern districts, the line of freezing extending to the central portion of the East Gulf States. Rather cool weather prevailed in most portions of the country during the latter half of the decade, but early in the second decade warm weather for the season again set in over most sections, continuing till shortly after the middle of the month, when lower temperatures were experienced in the Southeast, with freezing weather extending well into the Florida Peninsula and light frost occurring in the southern portion. Moderate temperature followed, continuing in most sections until near the middle of the third decade, when a cold wave of considerable severity overspread most central and eastern districts. The month closed with rather mild weather in most eastern sections, but with temperatures generally below the seasonal average in the West, and with a moderate cold wave moving into the central valleys.

For the month as a whole the temperature was above normal over much of the country, as has been the case during the preceding winter and late fall months, particularly in the northern districts. In some sections of the more northern States the temperatures have been almost constantly above the normal during the five months October to February, inclusive, the average excess during that period amounting to 5° or more per day.

In contrast with the high temperatures that have prevailed so continuously in the districts above mentioned, small areas west of the Rocky Mountains, particularly in the southern plateau and southern Rocky Mountain regions, have had almost continuous cold since early in November. This condition doubtless has been due largely to an unusually heavy fall of snow over these regions early in November, which in certain districts, particularly the elevated portions of northern Arizona and New Mexico and southern Utah and Colorado, remained unmelted throughout the following months, thereby tending to maintain a constant cold surface, which intensified cooling by radiation at night and hindered any material warming up during the day. As a result, temperatures remained unusually low over small local areas and new records of low monthly mean temperatures were established at a few points. (See article in March, 1919, REVIEW.)

PRECIPITATION.

The month opened with precipitation in the far Southwest, the first of importance in that region for about two months, and during the next several days it extended over practically all districts, except the Northwest. There was heavy snowfall in the southern Rocky Mountain region, and the rainfall was rather heavy in portions of the Gulf States, but elsewhere precipitation was mostly light. Near the latter part of the first decade light rains fell locally in the South, and rather heavy precipitation occurred along the North Pacific coast.

Early in the second decade there was heavy rainfall in central and northern California, and lighter falls were general throughout the Pacific Coast States. The precipitation area gradually extended eastward, and near the middle of the month had developed into a storm of considerable severity and wide extent over the central valleys, the falls becoming heavy in portions of the Gulf States and Ohio Valley. Except for light precipitation from the Rocky Mountains westward, fair weather prevailed during the latter half of the second decade.

The remainder of the month was mostly cloudy and wet, and about the middle of the third decade the rainfall was quite heavy in the South, particularly in Alabama, Georgia, and northern Florida. The month closed with a storm of considerable intensity over the middle Mississippi Valley, and rain or snow was falling over large areas between the Mississippi River and Rocky Mountains and in the far Northwest. In the East, South, and far Southwest the weather was generally fair.

For the month as a whole precipitation was heavy and considerably above the normal in the Gulf States; but elsewhere east of the Mississippi River the amounts were generally moderate to light, and mainly below the normal. From the middle and upper Mississippi Valley westward to the Pacific, precipitation was mainly above the normal, the excess being quite pronounced in portions of California and Arizona, but elsewhere rather small. As usual the precipitation was unevenly distributed in the mountain regions of the West, the monthly amounts ranging from only a trace in the lower Colorado River Valley to more than 20 inches in some elevated districts of the Sierra Nevada. The monthly amounts were mostly small and below normal from Texas westward to southern California.

SNOWFALL.

From 10 to 14 inches of snow fell during the month north of a line from southern Kansas northeastward to lower Michigan, and in the northern New England States; elsewhere east of the Rockies the snowfall was unusually

light for February. Scarcely more than 1 inch fell in the Ohio Valley during the entire month, and from Tennessee and Arkansas southward little or none was recorded. In the mountain districts of the West, however, the month brought heavy snows over extensive areas where the amounts during the preceding months had been exceedingly scant. This was particularly true in the Sierra of California and the adjacent mountains of Nevada and Oregon, where the stored amounts up to the end of January had been in some instances the least of record. The heavy falls during February brought the average depths to normal or above; but while good depths prevailed, the snow lacked the dense condition it attains when the falls occur earlier in the season, and it will naturally melt more rapidly with the approach of warm weather. However, the amounts were generally sufficient to alleviate danger of any material shortage in water for irrigation or other purposes during the coming summer. In other portions of the western mountains the snowfall was mainly close to or above the normal; and while the amounts now stored are not usually in excess of the normal, the snow has accumulated slowly, and is reported as well packed and containing a good percentage of water.

RELATIVE HUMIDITY.

There was much local variation in the relative humidity but it was above normal in the main from the Mississippi River westward and below the normal to the eastward. Excesses were most pronounced at points in the middle Plains region and locally in central California, where they ranged from 8 to 15 per cent. The deficiencies were not so pronounced.

STORMS AND HIGH WINDS.

The month was mostly free from severe storms or notably high winds, although in portions of the country, particularly in some of the mountain States of the West, the month was classed as unusually windy.

Average accumulated departures for February, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	° F.	° F.	° F.	In.	In.	In.	P. ct.		P. ct.	
New England	28.6	+3.1	+ 8.2	2.51	−0.80	+1.70	4.9	−0.5	71	−3
Middle Atlantic	35.8	+3.0	+ 7.8	2.46	−0.80	−0.90	5.1	−0.4	70	−3
South Atlantic	47.3	−0.5	+ 2.1	3.85	−0.20	−0.50	5.3	+0.1	74	−1
Florida Peninsula	66.3	−1.0	− 2.1	3.54	+1.00	0.00	5.9	+1.7	77	−3
East Gulf	50.1	−0.7	− 1.1	7.00	+2.20	+2.90	6.1	+0.6	75	0
West Gulf	49.3	−0.3	0.0	2.49	−0.20	−0.10	5.2	+0.3	74	0
Ohio Valley and Tennessee	36.8	+1.2	+ 5.0	1.91	−1.70	−2.90	6.6	+0.4	74	−1
Lower Lakes	29.1	+4.4	+10.5	1.31	−1.10	−2.60	7.1	+0.3	76	−4
Upper Lakes	24.3	+5.1	+12.6	1.86	0.00	−1.30	7.1	+0.8	81	0
North Dakota	7.6	+0.7	+16.4	0.73	+0.20	−0.20	6.3	+1.3	86	+5
Upper Mississippi Valley	28.4	+3.8	+11.5	2.17	+0.50	−1.00	5.8	+0.5	79	0
Missouri Valley	26.9	+2.5	+13.2	1.88	+0.80	−0.10	6.0	+0.8	80	+4
Northern slope	21.1	−0.4	+10.1	1.02	+0.30	−0.30	6.0	+0.8	75	+2
Middle slope	33.2	+0.8	+ 5.2	1.54	+0.80	+0.20	5.4	+0.9	76	+9
Southern slope	45.4	+0.8	− 2.5	0.44	−0.40	−0.20	3.9	−0.6	55	−7
Southern Plateau	40.3	−4.6	− 6.2	0.45	−0.10	−0.70	3.4	−0.2	53	+5
Middle Plateau	32.9	−0.1	− 0.5	1.44	+0.30	−0.60	6.7	+1.5	70	+3
Northern Plateau	34.1	+2.0	+ 5.6	1.96	+0.60	+0.20	8.1	+1.7	76	+1
North Pacific	42.0	+0.7	+ 3.1	6.02	+0.70	+2.70	7.8	+0.6	84	+2
Middle Pacific	47.6	−1.4	− 0.3	5.82	+3.00	+1.50	6.8	+1.2	82	+5
South Pacific	51.7	−1.1	+ 2.7	2.33	−0.10	−2.00	5.0	+0.6	74	+3

Winds of 50 mis./hr. (22.4 m./sec.) or over, during February, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Alpena, Mich.	28	52	s.	New York, N. Y.	16	62	nw.
Block Island, R. I.	1	55	nw.	Do.	18	60	nw.
Do.	16	60	nw.	Do.	19	52	nw.
Do.	17	50	nw.	Do.	23	62	nw.
Do.	26	60	nw.	Do.	24	56	nw.
Buffalo, N. Y.	23	60	sw.	Do.	26	66	nw.
Do.	28	62	sw.	Do.	28	53	s.
Cheyenne, Wyo.	11	52	sw.	North Head, Wash.	8	66	se.
Do.	22	58	w.	Do.	9	56	se.
Do.	25	50	sw	Do.	12	60	se.
Chicago, Ill.	28	50	sw	Do.	16	50	s.
Dallas, Tex.	12	55	sw.	Do.	24	60	s.
Dayton, Ohio.	28	62	sw.	Do.	25	76	se.
Del Rio, Tex.	12	56	nw.	Do.	27	78	se.
Detroit, Mich.	28	62	w.	North Platte, Nebr.	13	52	nw.
Duluth, Minn.	3	57	nw.	Oklahoma, Okla.	13	58	nw.
Do.	24	54	w.	Pensacola, Fla.	13	50	s.
Eastport, Me.	23	59	ne.	Point Reyes Light, Calif.	8	60	s.
Ellendale, N. Dak.	14	50	nw.	Do.	9	72	se.
El Paso, Tex.	12	62	w.	Do.	10	71	s.
Do.	24	52	w.	Do.	11	72	nw.
Do.	27	56	w.	Do.	12	54	nw.
Erie, Pa.	22	60	se.	Do.	15	50	nw.
Do.	23	52	sw.	Do.	17	73	nw.
Evansville, Ind.	28	52	w.	Do.	18	50	nw.
Fort Smith, Ark.	13	52	sw.	Do.	19	58	nw.
Do.	28	52	w.	Do.	20	71	nw.
Hatteras, N. C.	10	54	n.	Do.	21	56	nw.
Jacksonville, Fla.	14	50	sw.	Do.	23	72	nw.
Lexington, Ky.	28	56	sw.	Do.	24	51	nw.
Louisville, Ky.	13	50	s.	Do.	26	60	sw.
Do.	28	60	sw.	Port Huron, Mich.	28	54	w.
Memphis, Tenn.	13	56	sw.	Providence, R. I.	16	54	nw.
Modena, Utah.	26	66	s.	Do.	24	55	nw.
Mount Tamalpais, Cal.	6	58	s.	Do.	26	60	nw.
Do.	8	54	s.	Saint Louis, Mo.	28	52	w.
Do.	9	62	s.	Salt Lake City, Utah	26	52	nw.
Do.	10	66	s.	Sandusky, Ohio.	28	56	sw.
Do.	11	56	nw.	Sandy Hook, N. J.	26	60	nw.
Do.	12	52	nw.	Tatoosh Island, Wash.	4	80	sw.
Do.	21	50	s.	Do.	7	54	e.
Do.	25	50	s.	Do.	8	62	se.
Do.	26	58	s.	Do.	9	54	sw.
Do.	28	50	se.	Toledo, Ohio.	28	72	sw.
New York, N. Y.	1	50	nw.	Wichita, Kans.	13	53	w.
Do.	2	50	nw.				

SPECIAL FORECASTS AND WARNINGS—WEATHER AND CROPS.

WEATHER WARNINGS.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated: Weather Bureau, Washington, Mar. 15, 1919.]

Storm warnings.—There was no occasion for special forecasts until the evening of the 9th, at which time a western disturbance had reached the North Carolina coast with a northeastward movement. At the same time a disturbance was approaching Bermuda from the southward, and advisory warnings were issued for strong north winds at sea north of the Virginia capes. Strong winds and gales occurred as forecast. There was also a disturbance of marked intensity over Alberta moving southeastward, and warnings of strong northeast winds with snow or rain were sent to open ports on Lake Michigan. This disturbance moved due eastward with decreasing intensity, and no strong winds occurred.

On the night of the 12th a severe disturbance from the north Pacific was central over the Texas Panhandle with general low pressure east of the Rocky Mountains, and at 10 p. m. warnings were ordered on the Gulf coast from Bay St. Louis, Miss., to Cedar Keys, Fla., for strong southeast winds on the following day. On the morning of the 13th the storm was over northwestern Missouri, with a barometer reading of 28.90 inches at Kansas City, and fresh southerly gales were blowing over northeastern Gulf of Mexico. Southwest warnings were then ordered at Tampa, Fla., and along the Atlantic coast from Jupiter, Fla., to Fort Monroe, Va. Strong northeast to north gales, with snow and lower temperatures were also forecast for the Upper Lake Region, and strong shifting winds for the Ohio Valley, Tennessee, and the Lower Lake Region. At 5 p. m. southeast storm warnings were ordered along the Atlantic coast north of Fort Monroe, and the warnings along the Gulf coast from Bay St. Louis to Cedar Keys were changed to northwest. Winds occurred as forecast over all districts, except along the Maine coast, the disturbance having diminished in intensity, and divided after leaving northern Illinois. On the night of the 14th, with a secondary disturbance off the New Jersey coast, northeast storm warnings were displayed at Eastport, Me., but only fresh winds occurred, notwithstanding the very low pressure.

On the morning of the 15th, when the steamship *George Washington* was leaving France with the President of the United States on board, the following special message was sent to the Navy Department, Washington, D. C.:

> Strong shifting winds and gales and stormy weather will prevail over the entire North Atlantic Ocean for the next several days. Marked depression off the New England coast moving northeastward, and severe storm near the Azores with barometer this morning 28.90 inches and maximum wind velocity of 84 miles an hour from south.

From reports received later it appears that this forecast was fully verified.

As abnormally low pressure continued along the North Atlantic coast, with a rapid rise over the interior, northwest storm warnings were ordered at 5 p. m. from Delaware Breakwater, Del., to Newburyport, Mass., for strong west and northwest winds, snow, and colder weather. These warnings were fully verified as to wind and temperature, New York City, and Block Island, R. I., reporting maximum wind velocities of 64 and 56 miles and hour, respectively, from the northwest, but there was no snow south of New England.

A disturbance of the "Southwestern" type was central on the evening of the 19th over northern Arizona, moving east-northeastward with increasing intensity, and small craft warnings for fresh to moderately strong southeast winds were ordered displayed at 8 a. m. of the 20th along the Middle Gulf coast. The winds occurred as forecast, and at 11 a. m. of the 20th, with the disturbance central over southeastern Kansas, small-craft warnings were ordered displayed at Tampa, Fla., and along the South Atlantic coast from Jacksonville to Cape Henry for fresh to moderately strong east and southeast winds. However, the disturbance rapidly disintegrated during the 20th, and only local fresh winds occurred.

Another disturbance of similar origin was over Lake Huron on the evening of the 20th with rapid northeastward movement and increasing intensity, and at 10.30 p. m. southwest storm warnings were ordered from Delaware Breakwater, Del., to Portland, Me. At 11 a. m. of the 23d southeast warnings were also ordered east of Portland. Strong winds occurred as forecast, Eastport, Me., reporting a wind velocity of 56 miles an hour from the east.

Still another disturbance, from the North Pacific, really a redevelopment in the rear of a more moderate primary disturbance, was central on the morning of the 25th over southern Louisiana, with a strong and cold high area to the northwestward, and at noon northwest storm warnings were ordered from Bay St. Louis, Miss., to Carrabelle, Fla., for shifting winds becoming northwest and strong, with rapidly-falling temperature. Advisory warnings for fresh to moderately strong northwest winds had previously been issued to open ports on Lake Michigan, the primary disturbance at the time being a short distance northeast of Lake Superior. Again strong winds occurred as forecast.

On the evening of the 25th the secondary disturbance was central over extreme northeastern Florida, with another secondary over southeastern Virginia, and at 10.30 p. m. northwest storm warnings were ordered along the Atlantic coast from Jacksonville, Fla., to Nantucket, Mass. The primary disturbance was over eastern Ontario at this time, and on the following day strong winds and gales occurred as far north as the Massachusetts coast. On the morning of the 26th northwest warnings were ordered for the eastern Maine coast, but only fresh winds followed, the storm center having moved northeastward at some distance off the coast.

Again, on the evening of the 27th, another disturbance from the North Pacific was central over Oklahoma, with a cold high area to the northward, and southeast warnings were ordered on the Gulf coast from Bay St. Louis, Miss., to Carrabelle, Fla. Advisory warnings of snow, cold weather, and strong east and northeast winds were also sent to open ports on Lake Michigan. The forecast was fully verified as to Lake Michigan, but failed on the Gulf coast owing to the rapid northeastward movement of the storm center.

On the morning of the 28th with the storm central in marked form over extreme eastern Iowa, strong winds were forecast for the Ohio Valley and the entire lake region, and gales occurred generally during the day and night. At 5 p. m. southwest storm warnings were ordered along the Atlantic coast from Wilmington, N. C., to Portland, Me., but as the storm rapidly diminished in

intensity during the night there were no strong winds, except between Delaware Breakwater, Del., and Block Island, R. I.

There were no storms without warnings.

Cold wave and frost warnings.—Frost warnings were issued for some portions of the Southern States on the 4th, 6th, 9th, 10th, 15th, 16th, 17th, and 23d. All warnings were verified, except those of the 17th for central and northern Florida, and those of the 23d for Alabama, southern Georgia, and northern Florida. The frosts in Florida on the 10th and 11th were severe.

The first cold-wave warning of the month was issued on the 4th for portions of Michigan, and was only partially verified, both as to amount of fall in temperature and the lowest temperatures reached. The next warning was issued at 2 p. m. of the 9th for southern Alabama, southern Georgia, and extreme northwestern Florida, and a moderate cold wave occurred on the following morning. On the evening of the 24th warnings were issued for a cold wave within 36 hours over Michigan and northern Indiana, and extended on the following morning over the Lake Region, the Ohio and Lower Mississippi valleys, the East Gulf and the South Atlantic States, those in the South to occur within 48 hours. These warnings were well verified except in the South, no freezing temperatures occurring east of Alabama except in northwestern Georgia. On the evening of the 25th and the morning of the 26th the cold-wave warnings were extended over the Middle Atlantic States and New England, but they were not verified owing to the rapid eastward movement of one of the numerous western disturbances.

On the evening of the 27th and morning of the 28th cold-wave warnings were issued for the Lake Region, the Ohio Valley, and the East Gulf States, and in the evening for the Middle and South Atlantic States. These warnings also failed of verification, although there was a decided fall in temperature, except in the South Atlantic States.

No cold waves occurred without warning except local ones on the 9th, at Sault Ste. Marie, Mich., and Elkins, W. Va.

WARNINGS: OTHER DISTRICTS.

New Orleans, La., forecast district.—On the morning of February 3, the barometer was low over the Mississippi Valley. There was also a moderate but well-defined cyclonic movement of the atmosphere in the West Gulf region and an area of high pressure attended by low temperatures over the eastern Rocky Mountain region, the Missouri Valley, and the Plains States. Cold-wave warnings were issued for central and eastern Oklahoma, east Texas, except the immediate coast, northwest Louisiana, and western Arkansas, based on the LOW from the West Gulf region moving out and the high-pressure area dropping southward into that region. The low pressure did not move out of the West Gulf region and the cold wave was justified only over the extreme northern portion of the district.

An area of low pressure over the interior of Texas, with an area of high pressure and low temperatures over the Missouri Valley and the Plains States on the p. m. map of February 6 indicated cold waves in Oklahoma, Arkansas, the interior of east Texas, and northwest Louisiana, and warnings ordered for these areas failed of verification because of an area of low pressure which, reports the following morning showed, centered in the vicinity of Monterey, Mexico.

Low temperatures accompanying an area of high pressure, having its crest over the northern Rocky Mountain region, with an area of low pressure over the southern Rocky Mountain region on the evening of February 23 indicated that a cold wave would overspread the greater portion of this district; cold-wave warnings were orders at 9:30 p. m., February 23, for Oklahoma, the Texas Panhandle, and extreme northwestern Arkansas, and were repeated at 9:45 a. m. on the 24th, and extended at 1:00 p. m. over Arkansas, northwestern Louisiana, and the eastern portion of east Texas, and at night to the Louisianian coast. The cold-wave warnings were justified.

Cold-wave warnings were issued at 9:30 p. m. on the 27th for Oklahoma and extreme northwest Arkansas, and at 10:00 a. m. on the 28th for the remainder of Arkansas, Louisiana, and Houston and Port Arthur, Tex.; the warnings were justified.

No general cold waves occurred without warnings.

Small-craft warnings were issued on February 12 and 19 for the Texas coast, and storm warnings were issued for the Texas and the Louisiana coasts on the 12th and 25th; the warnings were justified.

No general storm occurred without warnings.

Live-stock warnings were distributed on the 23d, 24th, 25th, 27th, and 28th.

Fire-weather warnings were distributed to Oklahoma and Arkansas on the 27th.—*I. M. Cline.*

Chicago, Ill., forecast district.—The first cold-wave warnings of the month were issued on the morning of February 3, and covered north-central Iowa, extreme eastern Minnesota, and western and northern Wisconsin, and were extended during the afternoon to include the balance of Wisconsin, and Dubuque and Davenport, Iowa. Practically all of these warnings were verified.

Cold-wave warnings were not issued again during the month until the morning of the 23d, when a marked cold high area appeared in the British Northwest. Warnings were then sent to southeastern Montana, east and central Wyoming, and the western portions of North and South Dakota and Nebraska. The evening of the same day warnings were extended eastward as far as Minnesota and northwestern Iowa, and during the 24th, eastward and southward, including the entire district. Advices were also sent to the stock interests of Wyoming, South Dakota, Nebraska, and western Kansas during the eastward movement of this cold wave. These warnings were for the most part fully verified, although the verifying limit was not reached at some points in the southwestern portion of the district.

From the 24th to the close of the month intense cold prevailed in Montana, the Dakotas, and Minnesota, but the rapid return to warmer weather over the southern and eastern portions of the district on the 27th, under the influence of a disturbance moving southeastward across the Middle Rockies and thence northeastward to the the Lake region necessitated the issuing of cold-wave warnings from southern Wyoming to the eastern limits of the district. With the exception of southern Wyoming, all these warnings were verified. The stock interests of South Dakota, Nebraska, and Kansas were fully advised of the approach of this cold wave which caused fresh to strong northerly winds, with snow, in the Southern Plain States.—*Ernest H. Haines.*

Denver, Colo., forecast district.—The month was notable for the large number of North Pacific LOWS, several of which developed into storms of such marked character

as to require special warnings. The LOW that appeared on the North Pacific coast on the 25th became one of the most severe storms of recent years in the central portion of the district.

On February 1 a disturbance of marked intensity was central in southern Nevada, and warnings of heavy snow in northern Arizona, southwest Colorado, and northwest New Mexico and high winds in Utah and northern Arizona were issued. Several inches of snow fell over the area covered by the warnings. Press dispatches from Flagstaff, Ariz., stated:

> A cold wind was causing drifting, which is said to be seriously interfering with train movements. Reports indicate that all of northern Arizona is in the grip of weather approximating blizzard conditions.

On the 11th a disturbance of considerable intensity was central in northern Nevada and warnings of strong westerly winds were issued for the western part of the district. By 8 p. m. the storm occupied the middle Rocky Mountain region and warnings of strong westerly winds were extended to New Mexico. It crossed the Divide by 8 a. m. of the 12th and the warnings were extended to the remainder of the district. During the passage of the storm across the district fresh to strong winds were general. The highest velocity reported was 60 miles an hour from the west in southern New Mexico. A disturbance developed in western Utah on the 17th, moved slowly eastward and reached western New Mexico on the morning of the 19th, when warnings of heavy snowfall in southern Colorado and northern New Mexico were issued. Many stations in southern Colorado reported several inches of snow. At Trinidad the snowfall was 8.8 inches. A storm of unusual intensity appeared on the North Pacific coast on the 25th. On the morning of the 26th the barometer reading at Tatoosh Island was 29.06 inches and the pressure was decreasing rapidly in the Plateau region. Warnings of strong southerly winds were issued on the 26th for Utah, New Mexico, and Arizona, and on the 27th for the entire district. At 8 a. m. on the 27th the storm was over northwest Colorado, with increased intensity, while an anticyclonic area occupied the Canadian border States from Montana eastward to Wisconsin and the pressure was rising in the Plateau region. The wind attained a velocity of 64 miles from the south at Modena and 52 miles per hour at Salt Lake City on the 26th and 30 to 56 miles in New Mexico and northern Arizona on the 27th. Snow slides were reported in several localities in the mountain districts and railroad officials reported the worst week experienced in years. Livestock warnings were issued for parts of Colorado on the 2d, 24th, and 27th and for northeast New Mexico on the 27th, and cold wave warnings in eastern Colorado on the 24th and in Colorado, north New Mexico, north Arizona, and southwest Utah on the 27th. The warnings were generally fully justified.—*Frederick W. Brist.*

San Francisco, Calif., forecast district.—Stormy weather was the rule rather than the exception in this district during February. Storm warnings were ordered on 14 days for some portion of the North Pacific coast; small craft warnings were displayed on four occasions, and three live-stock warnings were issued. Frost warnings were issued for some portion of California on 18 days. Most of the warnings were justified, although neither the storms nor the frosts were of unusual severity.

On February 8 about 10 miles south of Bellingham six men were washed overboard and drowned from the cannery tender *Uwanta*. The *Uwanta* was near the center of the bay, where the waves were unusually high, when she raced into the trough of a big wave and careened so far to the leeward as to spill five men into the sea. The captain, in endeavoring to rescue one of them, jumped into the water and was also drowned. Warnings for the storm were ordered at Bellingham at 6:40 p. m., February 7.

One of the most freakish storms on record developed suddenly over Vancouver Island on the morning of the 4th. A barometer reading of 29.00 inches was reported that day at 5 a. m. at Triangle Island. During this storm a maximum wind velocity of 80 miles from the southwest occurred at Tatoosh Island. The weather map the evening before did not indicate the proximity of such high winds and no warnings were issued. Our observer at Tatoosh reported there was not the slightest local indication of a violent blow 8 hours before the maximum velocity was reached. The storm disappeared almost as rapidly as it appeared, and the evening weather chart the same day showed scarcely a trace of it.

In a letter from the H. J. Dangberg Land & Live Stock Co., of Minden, Nev., dated February 25, 1919, the secretary of the company stated, "The weather reports (live-stock warnings) you have been sending us at different times are greatly appreciated and they have been of valuable assistance in several instances."

At Sacramento, Calif., there were six light and four heavy frosts, and at Fresno, Calif., the numbers were four and three, respectively. At both of these stations the minimum temperature for February was 33°, from roof exposures, while at Pomona, in the citrus district of southern California, the minimum temperature was 32°, or lower, on 14 days, with instruments exposed about 5 feet above the ground. Verifications of frost forecasts under these conditions are unsatisfactory, but it is believed most of those issued were verified, although some few were decided failures.—*E. A. Beals.*

RIVERS AND FLOODS, FEBRUARY, 1919.

By ALFRED J. HENRY, Meteorologist in Charge.

There were no severe floods during the month. Flood stages due to moderate rains occurred in the South and in northern California as indicated in the paragraphs below.

The high water in the Santee River in South Carolina that was in progress at the end of January had fallen below flood stages by the 12th, but moderate rain on the 14th caused it to pass the flood stage again by the 16th.

The Pearl River at Jackson, Miss., was at flood stage from the 7th to the 9th.

General rains of moderate intensity in the South Atlantic and East Gulf States from the 20th to the 26th caused most of the rivers in these districts to slightly exceed flood stages during the last week of the month. But little damage was suffered owing to timely warnings.

Moderate to heavy rains during the second week of the month caused a sharp rise in the Sacramento River. Owing to the reclamation of Sutter Basin, the water which flowed through Moulton Break into Butte Slough was forced to the north and east of Sutter Basin and it spread over several thousand acres, causing damage estimated at several hundred thousand dollars.

The Willamette River at Eugene and Oregon City, Oreg., was in slight flood on the 10th and 12th. The usual tabular matter follows:

TABLE I.—*Flood stages in the Atlantic drainage during February, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Tar:	*Feet.*			*Feet.*	
Greenville, N. C.	13	.....	.....	12.2	28
Neuse:					
Neuse, N. C.	14	.....	.....	13.8	25
Smithfield, N. C.	14	25	27	15.1	26
Cape Fear:					
Elizabethtown, N. C.	22	25	(1)	25.2	25
Fayetteville, N. C.	35	.....	.....	31.8	24
Peedee:					
Cheraw, S. C.	27	24	24	31.2	24
Do.	27	27	27	29.0	27
Santee:					
Rimini, S. C.	12	(2)	10	17.0	3 31
Do.	12	16	(1)	16.6	28
Ferguson, S. C.	12	(2)	12	13.9	1–2
Do.	12	15	(1)	13.7	28
Catawba:					
Cawtaba, S. C.	11	23	23	12.0	23
Wateree:					
Camden, S. C.	24	24	26	29.8	24
Congaree:					
Columbia, S. C.	15	.....	.....	14.8	23
Broad:					
Blair, S. C.	15	23	23	15.0	23
Saluda:					
Chappells, S. C.	14	24	25	15.7	24
Edisto:					
Edisto, S. C.	6	.....	.....	5.5	28
Oconee:					
Milledgeville, Ga.	22	26	27	27.0	26
Dublin, Ga.	22	28	(1)	23.0	28
Ocmulgee:					
Macon, Ga.	18	25	26	20.6	26
Hawkinsville, Ga.	29	.....	.....	26.2	28
Abbeville, Ga.	11	3	3	11.0	3
Do.	11	26	(1)	14.4	28
Lumber City, Ga.	15	.....	.....	14.3	28

[1] Continued into March. [2] Continued from January. [3] January.

TABLE II.—*Flood stage in the East Gulf drainage during February, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Flint:	*Feet.*			*Feet.*	
Woodbury, Ga.	10	.....	.....	9.3	26
Montezuma, Ga.	20	28	(1)	20.8	28
Albany, Ga.	20	27	(1)	24.4	28
Bainbridge, Ga.	25	.....	.....	23.3	28
Chattahoochee:					
Eufaula, Ala.	40	26	(1)	48.5	27
Alaga, Ala.	30	26	(1)	39.6	28
Alabama:					
Montgomery, Ala.	35	26	(1)	44.8	28
Selma, Ala.	35	26	(1)	47.2	28
Tallapoosa:					
Milstead, Ala.	40	26	26	44.0	26
Coosa:					
Gadsden, Ala.	22	24	27	22.6	26
Lock No. 4 (Lincoln, Ala.)	17	23	(1)	20.0	23
Wetumpka, Ala.	45	.....	.....	43.8	27
Tombigbee:					
Demopolis, Ala.	39	26	(1)	45.4	28
Black Warrior:					
Tuscaloosa, Ala.	46	.....	.....	43.4	23–24
Pascagoula:					
Merrill, Miss.	20	.....	.....	19.4	28
Pearl:					
Jackson, Miss.	20	7	9	20.3	8
Do.	20	.....	.....	19.1	28
Columbia, Miss.	18	.....	.....	17.0	8
Do.	18	28	(1)	18.3	28

[1] Continued into March.

TABLE III.—*Flood stages in the Mississippi drainage during the month of February, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Illinois:	*Feet.*			*Feet.*	
Peru, Ill.	14	.....	.....	12.5	1
Henry, Ill.	7	(1)	2	7.1	1
Peoria, Ill.	16	.....	.....	14.2	1–2
Beardstown, Ill.	12	.....	.....	11.3	1–3
Sulphur:					
Finley, Tex.	24	.....	.....	21.7	11
Ringo Crossing, Tex.	20	.....	.....	17.9	4

[1] Continued from January.

TABLE IV.—*Flood stages in West Gulf drainage during month of February, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Trinity:	*Feet.*			*Feet.*	
Fort Worth, Tex.	20	.....	.....	19.3	2
Dallas, Tex.	25	2	7	33.3	4–5
Trinidad, Tex.	28	6	14	34.1	12
Liberty, Tex.	25	8	10	25.3	9
Do.	25	.....	.....	24.5	23
Sabine:					
Logansport, La.	25	.....	.....	22.0	2

TABLE V.—*Flood stages in Pacific drainage during month of February, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Sacramento:	*Feet.*			*Feet.*	
Red Bluff, Cal.	23	11	11	24.7	11
Monroeville, Cal.	20	.....	.....	17.4	12
Knights Landing, Cal.	18	.....	.....	17.9	12
Sacramento, Cal.	29	.....	.....	28.6	11
Benson Ferry, Cal.	12	12	12	12.4	12
Fernbridge, Cal.	15	10	10	17.3	10
Williamette:					
Eugene, Oreg.	10	10	10	10.0	10
Oregon City, Oreg.	10	10	13	11.2	12

MEAN LAKE LEVELS DURING FEBRUARY, 1919.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Mar. 7, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during February, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean seal level at New York	602.08	580.66	572.20	245.91
Above or below—				
Mean stage of January, 1919	−0.18	−0.14	+0.01	−0.18
Mean stage of February, 1918	+0.43	−0.16	+0.55	−0.07
Average stage for February, last 10 years	+0.33	+0.79	+0.67	+0.50
Highest recorded February stage	−0.40	−2.06	−1.55	−1.76
Lowest recorded February stage	+1.32	+1.50	+1.57	+2.08
Average relation of the February level to—				
January level	.....	±0.0	±0.0	+0.1
March level	.....	−0.1	−0.2	−0.2

[1] Lake St. Clair's level: In February, 575.02 feet.

EFFECT OF WEATHER ON CROPS, FEBRUARY, 1919.

By J. WARREN SMITH, Meteorologist.

The weather during February was generally favorable for the growth of field and garden crops in most southern districts and for winter grains in the Central States. Growth was retarded in California, however, by cool weather, while low temperatures and heavy rains in the Southeast did some damage. Frequent rains delayed plowing and planting in many parts of the South, but the mild weather permitted much farm work in Central and Northern States. Corn planting was begun in Florida and southern Texas, and some cotton was planted in Florida and California.

Winter grains.—Moderate temperature and ample soil moisture were favorable for winter grains in most sections of the country, but there was some damage by freezing and thawing, with insufficient snow cover, in the Northeast and some blowing of the soil in the sandy districts of the Great Plains. The weather was favorable for winter oats, except for some damage by cold in Alabama and some complaint of rust in Texas.

The seeding of spring oats was hindered by wet soil in Oklahoma and some more eastern districts, but generally this work advanced during the month at about the normal rate.

Potatoes and truck crops.—Wet weather delayed the planting of potatoes and truck crops in parts of the South, but where soil conditions permitted this work progressed at about the average rate. Truck made favorable growth in Texas, but it was too cool in California and too cool and wet in the eastern Gulf region for best results.

Pastures, meadows and ranges.—Moderate temperature and sufficient moisture made conditions favorable for meadows, pastures, and ranges in most districts. The ranges were open and grazing was possible in many of the western grazing sections. The weather was generally favorable for stock, except for rather heavy losses in western Kansas, northwestern Oklahoma and in localities in eastern New Mexico.

Fruit.—The warm weather caused considerable swelling of fruit buds as far north as New Jersey and the Ohio Valley, while at the close of the month peaches, pears, and plums were blooming in the Gulf and South Atlantic coast districts, and almonds, apricots and plums in California. Very little winterkilling of fruit was reported.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatoligical service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest tepmeratures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by section, February, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	47.7	+0.6	Troy	80	22	Riverton	17	10†	6.93	+1.54	Milstead	13.00	Livingston	2.27
Arizona	41.7	−4.7	Sentinel	83	10	Chin Lee	−12	3	1.65	+0.35	Payson	4.94	4 stations	T.
Arkansas	44.1	+2.1	Pine Bluff	80	20	Gravette	−10	9	3.34	−0.28	Malvern	5.56	Rogers	1.44
California	45.7	−2.8	San Jacinto	83	11	Portola	− 9	24	7.46	+3.05	Helen Mine	26.58	Greenland Ranch	0.00
Colorado	23.1	−3.6	Las Animas	82	11	Hermit	−33	3	1.23	+0.23	Cumbres	4.98	Fairplay	0.06
Florida	60.2	+0.2	4 stations	88	22†	Orange City	24	11	4.91	+1.66	Pensacola	12.53	Key West	1.44
Georgia	49.5	+2.0	Columbus	79	22	2 stations	18	10	6.96	+1.83	Talbotton	9.98	Atlanta	4.41
Hawaii (January)	68.0	−0.3	Waianal	89	23	Glenwood	38	7	3.56	−3.55	Kukaiau Mill	16.09	3 stations	0.00
Idaho	28.5	+0.6	3 stations	56	9†	Stanley	−28	1	3.07	+1.15	Soldiers Creek	7.46	Fort Hall	0.73
Illinois	32.6	+5.2	2 stations	63	3†	Antioch	1	26	1.94	−0.31	Mount Carroll	3.10	Henry	1.21
Indiana	33.3	+4.2	3 stations	66	13	2 stations	8	8†	1.54	−1.34	Valparaiso	2.63	Scottsburg	0.55
Iowa	24.9	+4.4	2 stations	65	11	Spencer	−16	9	2.42	+1.27	Nora Springs	4.12	Lansing	1.08
Kansas	32.5	+1.7	Ashland	70	11	Utica	−11	28	1.83	+0.62	Ellinwood	4.29	Tribune	0.36
Kentucky	38.6	+3.0	Mount Sterling	69	22	3 stations	12	6	1.79	−1.81	Brownsville	3.14	Carrollton	0.87
Louisiana	53.9	+1.7	Schriever	82	28	Calhoun	22	27	5.71	+1.05	Franklinton	10.40	Calhoun	2.05
Maryland-Delaware	35.6	+2.9	Cambridge, Md	70	14	Oakland, Md	− 3	20	2.44	−0.62	Wilmington, Del	3.42	Western Port, Md	1.40
Michigan	24.5	+6.5	Cassopolis	56	12	Humboldt	−24	27	1.71	−0.14	Munising	3.10	Frankfort	0.64
Minnesota	13.0	+2.3	Caledonia	50	12	Red Lake	−38	27	1.41	+0.79	New Ulm	4.12	Argyle	0.27
Mississippi	49.2	+1.4	Fruitland Park	78	28	2 stations	13	10	5.42	+0.39	Shubuta	9.87	Swan Lake	2.52
Missouri	35.3	+4.0	Caruthersville	71	1†	Neosho	−10	9	1.98	−0.38	Warsaw	3.70	Mexico	1.03
Montana	20.2	−0.9	Valier	63	9	Savage	−37	28	1.07	+0.29	Heron	5.00	Graham	0.05
Nebraska	24.8	+0.3	Gothenburg	67	11	Bridgeport	−23	28	1.88	+1.13	Arden	4.82	Haigler	0.45
Nevada	33.5	+0.2	Las Vegas	75	9	Owyhee	− 3	19	1.63	+0.37	Marlette Lake	11.39	Indian Springs	0.09
New England	26.0	+3.8	North Grosvenor Dale, Conn.	54	14†	2 stations	24	10	2.43	−0.81	Kingston, R. I	5.06	Waterbury, Conn	0.43
New Jersey	33.6	+3.5	2 stations	65	14	Culvers Lake	4	11	3.39	−0.45	Long Branch	6.48	Layton	1.37
New Mexico	32.4	−4.1	Deming	81	11	Elizabethtown	−26	4	0.70	−0.09	Anchor Mine	3.87	7 stations	0.00
New York	27.2	+5.6	2 stations	60	28	2 stations	−20	11	1.89	−0.85	Lake Grove	4.47	Dansville	0.34
North Carolina	41.4	+0.3	Wenona	77	14†	Altapass	3	10	3.85	−0.38	Highlands	8.32	Altapass	1.54
North Dakota	7.8	−0.1	Mott	58	10	3 stations	−40	36†	0.69	+0.30	Lisbon	1.90	Pembina	0.02
Ohio	32.5	+5.0	Green	70	22	Medina	− 3	10	1.19	−1.42	Green	3.77	North Bass Island	0.32
Oklahoma	40.9	+1.9	4 stations	80	11†	Miami	− 2	9	1.90	+0.52	Broken Bow	3.65	Rankin	0.60
Oregon	37.1	−1.1	Drain	67	8	Hampton	−12	22	5.69	+0.86	Agness	16.29	Maury	0.65
Pennsylvania	32.0	+4.7	Derry	66	28	Ebensburg	− 7	11	2.23	−0.79	Phoenixville	4.27	Wellsboro	1.03
Porto Rico	74.6	+1.2	Comerio Falls	97	28	Lares	52	12†	1.22	−1.39	Arecibo	3.80	4 stations	0.00
South Carolina	47.5	+0.4	Paris Island	75	24	2 stations	17	11	4.73	+0.37	Yemassee	7.26		2.38
South Dakota	16.8	+0.8	Hermosa	60	11	Redig	−34	28	1.12	+0.74	Sioux Falls	2.77	Hermosa	0.10
Tennessee	41.2	+1.7	Newport	73	22	Mountain City	4	11	3.23	−1.16	Lookout Mountain	5.48	Savannah	1.98
Texas	49.5	−0.3	Falfurrias	94	12	Dalhart	8	4	1.93	+0.02	College Station	7.19	4 stations	0.00
Utah	29.3	−0.5	St. George	68	8	Thistle	−21	28	1.69	+0.30	Silver Lake	9.78	Green River	0.01
Virginia	37.9	+1.9	2 stations	72	14	Mount Weather	8	19	2.36	−0.74	Quantico	4.33	Hot Springs	0.94
Washington	35.1	+0.4	2 stations	62	10†	Snyders Ranch	−18	24	4.30	+0.78	Wind River	15.20	Wahluke	0.88
West Virginia	35.2	+3.3	Charleston	72	28	2 stations	− 2	11	1.85	−1.20	Green Sulphur Springs.	3.93	Upper Tract	0.35
Wisconsin	20.5	+5.2	Mount Horeb	59	12	Winter	−36	27	1.80	+0.64	Mondovi	3.22	Port Edwards	0.79
Wyoming	21.6	0.0	Pine Bluffs	61	11	Moran	−27	15	0.61	−0.12	Moran	2.85	Emblem	0.00

* For explanation of the following tables and charts, see this REVIEW, January, 1919, pp. 52–53.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, February, 1919.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England.							**28.6**	**+3.1**											**71**	**2.51**	**−0.8**										**4.9**		
Eastport	76	67	85	29.72	29.81	−0.17	25.0	+3.6	38	4	31	8	11	19	21	23	18	77	1.86	−1.8	9	8,990	nw.	59	ne.	23	9	8	11	5.7	11.8	4.4
Greenville	1,070	6	....	28.66	29.88	.....	18.2	.....	41	22	27	−4	21	10	38	.....	.....	.....	.....	2.27	.....	9	.....	.....	.....	.....	.....	17	3	8	....	22.8	30.0
Portland, Me	103	82	117	29.79	29.91	−.11	27.4	+3.5	43	25	34	12	27	21	22	23	15	62	2.34	−1.3	8	6,222	nw.	38	nw.	2	14	5	9	4.2	12.2	5.0
Concord	288	70	79	29.60	29.92	−.12	26.4	+2.8	44	4	35	4	12	18	33	.....	.....	.....	.....	1.94	−1.3	4	4,256	nw.	28	nw.	24	17	7	4	3.3	18.3	4.3
Burlington	404	11	48	29.52	29.98	−.05	21.6	+3.7	40	28	29	−2	11	14	30	.....	.....	.....	.....	1.02	−0.4	12	6,620	nw.	34	s.	28	9	7	12	6.0	13.4	4.0
Northfield	876	12	60	28.99	29.98	−.06	19.0	+1.8	39	28	29	−10	11	9	36	16	13	82	1.47	−0.8	9	4,572	n.	32	nw.	24	9	8	11	6.0	18.5	13.8
Boston	125	115	188	29.77	29.91	−.13	32.6	+4.6	52	28	40	16	11	25	23	28	21	64	2.66	−0.8	7	7,986	nw.	34	nw.	26	11	13	4	4.6	6.2	0.0
Nantucket	12	14	90	29.88	29.89	−.15	33.1	+0.5	45	24	38	20	12	28	17	30	25	75	1.86	−1.2	9	10,685	nw.	49	se.	14	11	10	7	5.1	7.4	0.0
Block Island	26	11	46	29.89	29.92	−.14	33.2	+2.0	47	28	38	19	11	28	17	31	28	80	3.81	−0.5	9	14,986	nw.	60	nw.	26	12	8	8	4.8	1.7	0.0
Providence	160	215	251	29.74	29.93	−.12	31.6	+2.6	47	28	39	15	11	24	22	28	21	66	3.09	−1.3	8	10,608	nw.	55	nw.	24	11	11	6	4.6	5.2	0.0
Hartford	159	122	140	29.78	29.96	−.10	31.5	+4.3	48	28	39	14	11	24	25	26	19	64	3.39	−0.2	9	5,440	nw.	31	nw.	1	14	4	10	5.1	8.5	0.0
New Haven	106	117	155	29.84	29.96	−.11	33.2	+4.9	50	28	40	16	11	26	23	28	22	68	4.22	+0.5	10	6,755	n.	35	n.	26	13	6	9	4.5	3.2	0.0
Middle Atlantic States.							**35.8**	**+3.0**											**70**	**2.46**	**−0.8**										**5.1**		
Albany	97	102	115	29.87	29.98	−.09	29.4	+5.8	50	28	36	12	11	23	27	25	21	74	1.68	−0.8	8	5,101	nw.	26	s.	28	13	9	6	4.4	6.8	0.0
Binghamton	871	10	69	29.03	29.99	−.09	29.5	+4.8	55	28	36	14	11	23	29	.....	.....	.....	.....	1.16	−0.7	11	4,682	nw.	27	se.	28	6	6	16	6.6	2.0	0.0
New York	314	414	454	29.62	29.97	−.11	34.7	+4.0	51	28	41	16	11	28	24	29	22	62	3.45	−0.3	11	13,275	nw.	66	nw.	26	12	4	12	5.2	0.7	0.0
Harrisburg	374	94	104	29.61	30.02	−.07	34.1	+4.2	55	28	40	20	11	28	25	29	22	64	2.06	−0.6	11	5,207	nw.	26	nw.	26	11	7	10	5.1	6.8	0.0
Philadelphia	117	123	190	29.88	30.01	−.09	37.6	+4.8	61	14	44	21	11	31	26	33	28	72	3.04	−0.3	11	7,387	nw.	32	n.	26	15	3	10	4.6	1.0	0.0
Reading	325	81	98	29.66	30.02	.....	34.6	.....	57	28	41	19	11	28	24	30	24	69	3.23	−0.3	12	6,140	nw.	32	nw.	16	13	5	10	5.4	1.5	0.0
Scranton	805	111	119	29.11	30.00	−.08	32.3	+5.4	58	28	39	18	11	26	27	29	26	85	2.13	−0.6	11	5,116	nw.	31	sw.	28	6	11	11	6.3	6.7	0.0
Atlantic City	52	37	48	29.93	30.00	−.11	35.8	+2.8	51	24	42	19	11	29	20	32	27	75	3.22	0.0	11	5,205	nw.	24	se.	25	14	6	8	4.2	0.5	0.0
Cape May	18	13	49	.....	30.03	−.08	36.4	+2.3	50	14	42	21	11	31	16	.....	.....	.....	.....	2.50	−0.8	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sandy Hook	22	10	57	29.96	29.98	.....	34.7	.....	49	28	40	20	11	30	17	31	27	74	3.41	.....	11	12,073	nw.	60	nw.	26	14	5	9	4.5	0.1	0.0
Trenton	190	159	183	29.77	29.98	.....	34.4	.....	58	28	41	17	11	28	27	30	25	72	3.25	+0.1	11	8,376	nw.	40	nw.	16	14	4	10	4.8	1.2	0.0
Baltimore	123	100	113	29.89	30.03	−.08	37.6	+3.0	59	14	44	22	11	32	20	32	25	64	2.62	−0.9	11	4,693	nw.	24	nw.	19	11	9	8	4.8	3.0	0.0
Washington	112	62	85	29.90	30.03	−.08	37.2	+2.7	60	14	44	21	11	31	24	32	26	68	2.01	−1.4	10	5,471	nw.	32	nw.	18	11	8	9	5.2	2.8	0.0
Lynchburg	681	153	188	29 26	30 03	−.08	39.8	+1.6	65	14	49	20	11	31	32	33	27	66	2.23	−1.3	8	5,077	nw.	33	s.	28	13	6	9	5.0	1.6	0.0
Norfolk	91	170	205	29.93	30.03	−.08	42.6	+0.8	68	14	50	26	11	36	27	37	31	70	2.15	−1.6	7	9,287	nw.	40	n.	26	14	6	8	4.5	T.	0.0
Richmond	144	11	52	29.88	30.04	−.07	39.8	−0.1	68	14	48	18	11	32	32	34	27	65	2.22	−0.9	9	5,418	se.	33	s.	28	13	3	12	5.1	0.0	0.0
Wytheville	2,293	49	55	27.58	30.03	−.09	34.5	−0.6	55	28	42	18	10	27	30	30	25	75	2.34	−1.8	11	4,936	w.	31	w.	15	8	8	12	5.6	0.4	0.0
South Atlantic States.							**47.3**	**−0.5**											**74**	**3.83**	**−0.2**										**5.3**		
Asheville	2,255	70	84	27.63	30.06	−.07	37.3	−1.2	58	12	45	16	11	29	32	32	28	74	2.01	−2.6	11	7,103	nw.	32	se.	22	9	7	12	5.9	2.3	0.0
Charlotte	773	153	161	29.17	30.02	−.10	42.8	−1.3	67	28	51	19	10	34	26	37	31	70	4.85	+0.5	11	4,149	n.	29	sw.	14	10	9	9	5.4	3.7	0.0
Hatteras	11	12	50	30.00	30.01	−.10	45.8	−0.8	63	14	52	29	11	40	19	42	38	80	2.39	−2.1	12	10,559	n.	54	n.	10	13	4	11	4.9	T.	0.0
Raleigh	376	103	110	29.62	30.03	−.08	42.7	−0.6	65	28	51	22	11	34	25	38	34	76	3.49	−0.8	11	5,505	n.	31	sw.	14	14	4	10	4.9	3.3	0.0
Wilmington	78	81	91	29.94	30.03	−.09	47.3	−0.4	68	28	56	24	11	39	23	42	38	76	2.83	−0.6	13	5,202	n.	27	sw.	14	13	7	8	4.5	1.2	0.0
Charleston	48	11	92	29.97	30.02	−.10	51.6	−0.1	70	23	58	32	10	45	21	46	41	74	5.51	+2.1	13	7,828	ne.	39	n.	26	10	7	11	5.4	0.0	0.0
Columbia, S. C	351	41	57	29 65	30.04	−.07	46.8	−1.0	69	28	56	26	10	38	28	40	34	69	3.50	−1.1	12	5,233	ne.	40	sw.	14	11	7	10	5.5	0.4	0.0
Greenville, S. C	1,013	113	122	28.90	30.01	.....	43.6	.....	64	1	52	22	10	35	28	37	30	68	6.48	.....	11	5,925	ne.	39	w.	14	13	4	11	4.9	0.2	0.0
Augusta	180	62	77	29 82	30 02	−.10	48.6	−0.4	70	28	58	26	11	40	32	44	41	81	4.83	+0.4	9	4,306	nw.	33	w.	14	11	4	13	5.9	T.	0.0
Savannah	65	150	194	29.95	30.02	−.10	52.8	+0.3	70	22	60	30	17	46	27	47	42	75	5.32	+2.0	13	9,142	nw.	44	w.	14	10	4	14	5.8	0.0	0.0
Jacksonville	43	200	245	29.98	30.02	−.10	57.6	+0.7	76	25	65	32	10	50	28	52	47	76	3.77	+0.3	11	9,368	nw.	50	sw.	14	10	6	12	5.6	0.0	0.0
Florida Peninsula.							**66.3**	**−1.0**											**77**	**3.54**	**+1.0**										**5.9**		
Key West	22	10	64	30.00	30.02	−.05	70.4	−0.4	83	28	75	55	11	65	17	64	61	79	1.44	−0.2	7	6,870	se.	38	sw.	14	14	7	7	4.4	0.0	0.0
Miami	25	71	79	30.01	30.04	.....	66.6	−2.2	82	3	74	41	17	60	24	61	58	78	3.20	+0.5	8	5,649	nw.	29	w.	15	8	7	13	6.1	0.0	0.0
Tampa	35	79	92	30.00	30.04	−.06	61.8	−0.5	83	24	69	38	11	55	26	55	51	75	5.98	+2.7	11	4,838	ne.	30	sw.	9	5	6	17	7.1	0.0	0.0
East Gulf States.							**50.1**	**−0.7**											**75**	**7.00**	**+2.2**										**6.1**		
Atlanta	1,174	190	216	28.76	30.02	−.10	44.4	−0.8	66	28	52	23	10	37	27	40	35	73	4.41	−0.2	9	8,679	nw.	40	nw.	9	9	4	15	6.3	0.1	0.0
Macon	370	78	87	29 62	30.02	−.10	48.6	−0.3	75	22	58	25	11	40	31	43	37	71	7.66	+3.1	11	4,550	nw.	28	nw.	9	6	8	14	6.3	T.	0.0
Thomasville	273	49	58	29 71	30.02	−.10	53.8	−1.2	73	28	62	29	10	46	29	48	44	77	8.86	+4.4	13	3,668	sw.	27	sw.	14	6	6	16	6.7	0.0	0.0
Pensacola	56	149	185	29.95	30.02	−.09	53.6	−1.9	74	22	60	31	10	47	24	50	48	82	12.53	+8.0	16	9,717	n.	50	s.	13	9	4	15	6.3	0.0	0.0
Anniston	741	9	57	29 22	30.03	−.09	44.8	−1.0	72	22	55	22	10	35	33	.....	.....	.....	4.69	0.0	13	5,113	se.	33	se.	20	8	9	11	6.1	T.	0.0
Birmingham	700	11	48	29.25	30.04	−.08	46.0	−2.3	69	22	55	23	10	37	28	40	34	69	5 22	+0.5	12	5,540	n.	32	s.	13	8	5	15	6.3	T.	0.0
Mobile	57	125	161	29.94	30.01	−.10	53.6	+0.4	78	22	62	31	10	45	28	48	44	76	7.49	+2.1	17	7,376	n.	44	nw.	26	8	4	16	6.1	0.0	0.0
Montgomery	223	100	112	29.78	30.04	−.08	50.2	−1.1	74	22	58	28	10	42	26	45	41	76	10.05	−4.5	14	4,903	n.	30	w.	14	6	12	10	5.6	0.0	0.0
Corinth	469	6	....	.....	.....	.....	44.7	.....	69	1	55	20	10	35	37	.....	.....	.....	3.60	.....	13	.....	s.	.....	.....	.....	.....	5	12	11	....	0.5	0.0
Jackson	304	5	....	.....	.....	.....	50.6	.....	76	20	61	24	26	40	36	.....	.....	.....	5.25	.....	12	.....	se.	.....	.....	.....	.....	6	17	5	....	0.0	0.0
Meridian	375	85	93	29.61	30.01	−.10	48.9	−0.2	73	21	58	27	10	39	36	43	38	72	5.69	+0.8	14	4,775	nw.	31	w.	14	10	8	10	5.5	T.	0.0
Vicksburg	247	65	74	29.73	30.02	−.08	50.8	−0.1	71	20	60	28	10	42	28	45	41	76	3.92	−0.7	14	6,073	se.	40	w.	13	8	9	11	5.8	T.	0.0
New Orleans	51	76	84	29.95	30.01	−.08	56.6	+0.3	75	28	64	36	10	49	28	52	49	81	6.52	+2.0	16	5,049	se.	30	n.	25	9	6	13	6.1	0.0	0.0
West Gulf States.							**49.3**	**−0.3**											**74**	**2.49**	**−0.2**										**5.2**		
Shreveport	249	77	93	29.74	30.02	−.07	49.6	−0.4	73	11	59	29	26	40	29	44	38	71	3.46	−0.2	13	6,063	nw.	38	w.	13	12	8	8	4.7	0.0	0.0
Bentonville	1,303	11	44	28.55	29.95	−.15	38.4	−0.1	65	11	49	3	9	28	45	.....	.....	.....	2.71	+0.2	13	5,115	s.	33	s.	27	16	3	9	5.0	7.8	T.
Fort Smith	457	79	94	29.48	29.98	−.12	43.2	+1.4	66	24	53	15	28	33	42	38	32	72	2.30	−0.4	12	7,613	e.	52	sw.	28	12	8	8	4.6	1.0	0.0
Little Rock	357	139	147	29.60	29.98	−.13	45.0	+0.9	69	12	54	22	9	36	30	39	33	67	3.55	−0.6	11	7,483	e.	40	w.	13	12	7	9	4.9	0.8	0.0
Brownsville	57	4	26	.....	.....	.....	62.6	.....	80	13	72	38	26	53	31	.....	.....	.....	1.08	.....	5	.....	n.	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	0.0
Corpus Christi	20	69	77	29.99	30.01	−.04	57.4	−0.3	78	12	64	37	26	51	27	53	50	80	1.03	−1.0	9	7,539	n.	48	se.	19	6	7	15	6.6	0.0	0.0
Dallas	512	109	117	29.44	30.00	.....	47.0	.....	72	11	56	25	28	38	35	.....	.....	.....	2.29	.....	7	6,992	s.	55	sw.	12	11	7	10	4.9	0.1	0.0
Fort Worth	670	106	114	29.26	29.99	−.08	47.3	−0.8	77	11	57	25	28	38	36	43	39	78	2.03	+0.8	6	8,100	s.	42	w.	13	11	7	10	4.6	T.	0.0
Galveston	54	106	114	29 97	30 03	−.04	55.4	−0.2	70	20	61	37	9	50	22	51	48	79	2.43	−0.7	12	8,512	se.	47	n.	25	8	8	12	5.7	0.0	0.0
Houston	138	111	121	29.86	30.02	.....	54.7	+0.7	72	11	63	32	9	47	28	.....	.....	.....	3.12	.....	12	6,148	nw.	36	e.	19	10	5	13	5.4	0.0	0.0
Palestine	510	64	72	29 47	30.01	−.07	49.2	−0.7	73	11	58	28	9	40	29	44	40	77	2.70	−0.7	11	6,037	se.	30	w.	13	10	7	11	5.4	0.0	0.0
Port Arthur	34	58	66	29.96	30.00	.....	54.2	.....	72	20	61	34	26	47	24	50	46	79	6.20	.....	12	7,190	n.	45	se.	19	7	8	13	6.0	0.0	0.0
San Antonio	701	119	132	29.28	30.01	−.04	53.0	−1.4	83	12	62	32	26	44	31	46	39	67	1.56	−0.2	6	5,986	nw.	44	nw.	25	11	5	12	5.2	0.0	0.0
Taylor	582	55	63	29.42	30.04	−.02	49.4	−1.9	79	12	59	28	9	40	35	.....	.....	.....	3.09	+0.5	10	6,243	nw.	44	nw.	12	11	4	13	5.6	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, February, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.							Total.	Departure from normal.	Days with .01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In*
							36.8	+1.2													74	1.91	−1.7										6.6		
Chattanooga	762	189	213	29.22	30.05	−.08	42.4	−1.3	68	22	50	25	10	34	26	37	31	68	5.18	+0.2	14	6,181	ne.	38	nw.	25	7	7	14	6.2	0.8	0.0
Knoxville	996	102	111	28.94	30.02	−.10	40.4	−0.4	67	13	49	23	11	32	30	36	31	75	2.78	−2.1	12	4,033	ne.	38	s.	14	7	6	15	6.5	1.3	0.0
Memphis	399	76	97	29.60	30.04	−.07	44.6	+1.3	69	12	53	21	9	36	28	40	35	71	2.66	−1.7	12	7,236	sw.	56	sw.	13	12	4	12	5.4	3.8	0.0
Nashville	546	168	191	29.44	30.04	−.08	41.2	+0.1	65	13	50	22	26	33	32	36	30	70	2.19	−2.1	11	6,595	se.	39	sw.	22	8	8	12	5.8	0.9	0.0
Lexington	989	193	230	28.94	30.04	−.07	36.0	+0.4	64	13	44	17	26	28	38	.....	.....	.....	1.61	−1.6	13	10,330	nw.	56	sw.	28	6	8	14	6.6	1.3	0.0
Louisville	525	219	255	29.44	30.04	−.07	37.8	+1.2	65	13	46	19	26	30	37	33	28	70	0.99	−2.8	9	9,140	s.	60	sw.	28	9	6	13	6.0	0.9	0.0
Evansville	431	139	175	29.54	30.02	−.09	37.7	+1.9	62	13	46	18	26	30	35	34	29	73	1.30	−1.8	7	9,470	sw.	53	w.	28	7	11	10	6.0	0.7	0.0
Indianapolis	822	194	230	29.09	30.00	−.10	33.2	+2.5	61	13	40	14	26	26	37	30	25	76	1.21	−1.9	11	9,432	s.	44	s.	28	4	7	17	7.2	1.3	T.
Terre Haute	575	96	129	29.35	29.99	.....	34.1	.....	60	13	42	15	8	26	35	31	27	79	1.57	.....	7	7,570	nw.	42	sw.	28	5	11	12	6.8	1.9	T.
Cincinnati	628	11	51	29.32	30.03	−.07	34.4	+2.0	64	13	43	15	26	26	41	30	26	73	1.05	−2.2	10	6,128	sw.	44	sw.	28	5	5	18	7.4	0.4	0.0
Columbus	824	173	222	29.11	30.01	−.08	32.6	+1.6	61	28	40	15	26	25	40	30	25	74	1.27	−1.8	15	8,777	nw.	46	w.	28	3	10	15	7.1	1.8	0.0
Dayton	899	181	216	29.00	29.98	.....	33.8	+3.8	59	28	41	16	26	26	39	30	26	78	1.11	−2.0	14	8,095	nw.	62	sw.	28	5	7	16	7.1	1.5	0.0
Pittsburgh	842	353	410	29.08	30.01	−.08	33.5	+1.7	65	28	41	17	26	26	25	30	25	74	1.58	−1.1	14	8,139	nw.	49	s.	28	4	4	20	7.5	1.7	0.0
Elkins	1,940	41	50	27.91	30.05	−.05	31.9	+0.4	62	28	42	5	11	22	36	27	24	79	2.04	−1.1	17	4,133	w.	34	w.	28	6	7	15	6.8	6.5	0.0
Parkersburg	638	77	84	29.37	30.04	−.06	35.8	+1.9	66	28	44	18	6	28	30	31	27	74	1.76	−1.5	14	4,166	se.	30	se.	22	6	3	19	7.1	1.6	0.0
Lower Lake Region.							29.1	+4.4													76	1.31	−1.1										7.1		
Buffalo	767	247	280	29.12	29.97	− .09	28.8	+4.8	60	28	35	14	26	23	33	26	22	76	1.61	−1.2	17	11,343	w.	62	sw.	28	4	7	17	7.1	7.6	0.0
Canton	448	10	61	29.48	29.98	.....	21.8	+3.8	49	28	30	− 1	18	14	30	.....	.....	.....	1.65	−0 9	10	6,120	w.	37	sw.	23	10	4	14	5.5	7.0	0.4
Oswego	335	76	91	29.60	29.98	− .08	27.8	+3.9	53	28	33	10	11	22	33	26	22	79	0.92	−1.6	15	8,092	nw.	34	nw.	24	4	2	22	8.0	12.2	0.5
Rochester	523	97	113	29.40	29.99	− .07	29.2	+5.3	55	28	35	12	11	23	31	26	20	70	1.43	−1.4	14	6,596	w.	34	w.	23	5	6	17	7.1	7.2	0.0
Syracuse	597	97	113	29.34	30.00	− .07	27.8	+4.0	54	28	34	12	10	22	31	.....	.....	.....	1.59	−0.2	12	8,305	nw.	41	s.	28	2	11	15	7.3	6.8	0.0
Erie	714	130	166	29.18	29.97	− .10	31.0	+4.9	61	28	37	14	11	25	28	28	24	75	1.23	−1.6	15	10,216	w.	60	se.	22	3	8	17	7.6	6.5	0.0
Cleveland	762	190	201	29.15	29.99	− .08	31.3	+4.5	61	28	37	17	26	26	35	29	24	74	1.11	−1.5	15	9,788	nw.	46	sw.	28	2	10	16	7.8	4.3	0.0
Sandusky	629	62	103	29.30	29.97	− .10	31.4	+4.3	60	28	38	16	10	25	38	.....	.....	.....	0.94	−1.4	13	8,791	w.	56	sw.	28	3	9	16	7.3	1.9	0.0
Toledo	628	208	243	29.29	29.99	− .08	31.0	+4.2	57	28	38	15	26	24	40	27	23	74	1.13	−0.8	12	9,385	w.	72	sw.	28	7	5	16	6.6	2.2	0.0
Fort Wayne	856	113	124	29.04	30.00	.....	30.9	+4.1	55	12	38	9	26	24	40	28	24	78	1.51	.....	12	6,258	w.	47	sw.	28	4	10	14	7.0	3.5	T.
Detroit	730	218	245	29.17	29.99	− .07	29.4	+4.4	53	28	36	11	26	23	34	27	24	81	1.50	−0.7	14	8,264	w.	62	w.	28	4	8	16	7.0	3.1	0.0
Upper Lake Region.							24.3	+5.1													81	1.86	0.0										7.1		
Alpena	609	13	92	29.28	29.98	− .05	22.7	+4.9	39	28	29	0	27	16	26	22	18	83	1.85	+0.1	12	8,627	w.	52	s.	28	5	7	16	6.9	12.3	3.0
Escanaba	612	54	60	29.29	29.99	− .07	22.0	+6.7	37	12	28	− 8	27	16	33	21	19	88	2.11	+0.8	13	6,944	nw.	40	n.	15	9	7	12	5.6	15.5	7.0
Grand Haven	632	54	92	29.26	29.97	− .08	28.0	+3.8	46	3	33	10	27	23	28	26	22	79	2.94	+1.0	17	7,688	w.	38	w.	28	1	8	19	8.2	11.5	0.2
Grand Rapids	707	70	87	29.18	29.98	− .07	28.5	+3.0	45	3	34	9	26	23	27	25	21	76	2.16	+0.2	13	5,242	se.	27	w.	26	4	5	19	7.9	6.2	T.
Houghton	684	62	99	29.22	29.97	− .08	21.9	+5.9	42	11	28	1	26	16	26	.....	.....	.....	2.18	+0.5	19	7,978	e.	44	w.	25	0	4	24	9.2	19.7	14.5
Lansing	878	11	62	29.00	29.97	.....	27.0	+5.4	45	28	34	6	10	20	28	24	21	82	1.50	−0.5	12	5,207	w.	34	sw.	28	3	6	19	7.7	2.1	T.
Ludington	637	60	66	29.24	29.96	.....	26.9	.....	42	3	32	6	26	22	30	25	22	84	1.56	.....	15	7,911	e.	42	nw.	28	1	7	20	7.9	8.4	T.
Marquette	734	77	111	29.17	30.00	− .05	23.3	+7.4	39	11	29	− 6	27	18	30	22	18	81	1.50	−0.2	12	8,042	w.	41	nw.	28	1	6	21	8.4	14.2	11.7
Port Huron	638	70	120	29.25	29.97	− .08	27.6	+5.6	53	28	34	10	26	22	31	26	23	83	1.18	−1.0	13	8,428	nw.	54	w.	28	4	8	16	7.5	3.6	0.0
Saginaw	641	48	82	29.25	29.97	.....	26.6	.....	47	28	34	7	10	20	27	24	20	80	1.92	−0.2	11	7,209	w.	39	sw.	28	7	7	14	6.5	3.2	0.0
Sault Sainte Marie	614	11	61	29.26	29.99	− .04	20.0	+6.6	38	13	28	−13	9	12	32	18	15	80	1.24	−1.7	14	6,765	e.	40	w.	23	8	3	17	6.7	13.0	8.5
Chicago	823	140	310	29.07	29.99	− .09	30.5	+5.1	52	3	36	11	26	25	32	28	23	72	2.78	+0.6	11	8,583	nw.	50	sw.	28	8	6	14	6.5	6.6	T.
Green Bay	617	109	144	29.28	29.97	− .09	23.0	+5.8	40	11	30	− 6	26	16	32	21	17	78	1.51	−0.1	9	8,756	w.	38	ne.	14	5	8	15	6.9	8.0	3.5
Milwaukee	681	119	133	29.21	29.97	− .09	27.1	+5.2	50	11	34	0	26	21	30	24	20	76	2.20	+0.3	9	8,056	w.	48	e.	13	9	5	14	5.4	8.9	0.6
Duluth	1,133	11	47	28.74	30.02	− .06	13.8	+0.2	35	11	21	−22	27	6	27	12	10	88	0.94	0.0	8	10,696	w.	57	nw.	3	11	4	13	5.8	10.6	5.5
North Dakota.							7.6	+0.7													86	0.73	+0.2										6.3		
Moorhead	940	8	57	29.04	30.14	+ .03	9.7	+2.7	35	11	17	−25	25	2	28	8	5	84	0.58	−0.2	9	5,805	n.	28	n.	13	10	5	13	5.8	5.8	4.2
Bismarck	1,674	8	57	28.26	30.15	+ .03	10.0	+1.7	52	10	18	−24	25	2	36	9	7	88	0.63	+0.1	11	5,650	nw.	25	nw.	14	5	11	12	6.1	8.3	5.8
Devils Lake	1,482	11	44	28.45	30.12	+ .01	3.6	−0.9	39	10	12	−32	26	−5	30	3	2	92	0.70	+0.2	6	5,801	nw.	31	n.	13	6	8	14	6.6	9.6	6.7
Ellendale	1,457	10	56	28.45	30.09	.....	10.9	.....	44	10	19	−30	25	3	30	9	7	88	0.74	.....	6	9,778	ne.	50	nw.	14	2	12	14	7.1	10.7	6.9
Grand Forks	835	12	89	.....	.....	.....	5.6	.....	33	11	14	−27	26	−3	31	5	.....	.....	0.45	.....	6	.....	nw.	32	nw.	13	6	9	13	.....	5.0	8.0
Williston	1,872	41	48	28.01	30.10	− .01	7.2	−0.7	49	10	16	−28	28	−2	36	7	4	82	1.02	+0.6	10	4,506	n.	36	w.	10	4	12	12	6.8	5.5	3.0
Upper Mississippi Valley.							28.4	+3.8													79	2.17	+0.5										5.8		
Minneapolis	918	10	208	28.98	30.00	.....	16.4	.....	37	12	24	−13	27	9	38	.....	.....	.....	2.02	+1.3	7	8,663	nw.	43	nw.	28	6	11	11	6.2	11.8	5.1
St. Paul	837	201	236	29.09	30.03	− .06	17.0	+2.0	38	12	24	−11	25	9	38	.....	.....	.....	2.52	+1.7	7	9,061	nw.	38	nw.	24	7	9	12	6.2	14.8	5.3
La Crosse	714	11	48	29.20	30.01	− .07	22.4	+4.0	52	12	30	− 4	26	15	28	.....	.....	.....	2.07	+1.0	9	4,272	nw.	25	ne.	13	8	9	11	5.8	14.0	10.2
Madison	974	70	78	28.91	30.01	− .06	23.7	+4.1	52	11	31	− 2	26	16	30	21	17	79	2.12	+0.6	9	7,144	nw.	31	nw.	25	6	9	13	6.6	11.0	4.8
Wausau	1,247	4	.....	28.61	30.00	.....	17.6	.....	38	11	25	−14	26	10	27	.....	.....	.....	1.45	.....	8	.....	nw.	.....	.....	.....	12	3	13	5.5	12.6	10.3
Charles City	1,015	10	49	28.89	30.01	− .09	20.6	+5.5	48	12	28	− 5	25	13	32	19	17	87	2.56	+1.6	11	5,694	nw.	26	s.	10	9	7	12	5.9	15.4	7.0
Davenport	606	71	79	29.30	29.99	− .11	28.2	+4.4	59	11	37	4	7	20	39	26	22	82	2.20	+0.6	8	6,126	e.	34	w.	28	12	3	13	5.7	9.7	1.2
Des Moines	861	84	97	29.05	29.98	− .13	26.5	+2.4	57	11	35	− 1	7	18	30	24	20	80	3.00	+1.9	12	5,897	nw.	35	nw.	28	11	2	15	6.1	14.4	2.5
Dubuque	698	81	96	29.23	30.02	− .07	25.7	+4.1	55	11	33	2	25	18	31	23	20	81	2.87	+1.5	10	5,023	nw.	24	ne.	13	8	7	13	6.1	13.5	5.2
Keokuk	614	64	78	29.30	30.00	− .11	31.4	+4.8	63	11	40	6	28	23	36	28	24	77	1.57	0.0	9	6,130	w.	43	w.	28	14	4	10	5.0	5.1	T.
Cairo	356	87	93	29.60	30.00	− .11	39.6	+2.0	60	12	48	18	9	31	33	35	29	70	1.25	−2.1	9	7,518	s.	44	sw.	28	11	4	13	5.8	1.1	0.0
Peoria	609	11	45	29.30	29.99	− .11	30.8	+4.9	56	12	39	8	8	23	34	28	25	85	2.32	−0.4	10	5,559	nw.	38	w.	28	12	4	12	5.6	9.8	0.1
Springfield, Ill	644	10	91	29.28	29.97	− .13	32.9	+3.8	57	11	41	12	9	25	33	29	26	79	2.15	−0.6	7	6,847	nw.	34	w.	28	8	5	15	6.2	5.1	0.1
Hannibal	534	74	109	29.38	29.97	− .14	33.3	+4.2	60	11	42	10	9	25	37	.....	.....	.....	2.22	+0.6	9	6,726	nw.	37	w.	28	12	3	13	5.5	8.2	T.
St. Louis	567	265	303	29.36	29.98	− .13	36.7	+3.2	59	11	45	16	9	28	33	32	26	68	1.54	−1.2	8	10,403	nw.	52	w.	28	13	7	8	4.5	3.1	0.0
Missouri Valley.							26.9	+2.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	80	1.88	+0.8										6.0		
Columbia, Mo	781	11	84	29.12	29.97	− .14	35.1	+ 5.0	63	12	44	10	28	20	37	.....	.....	.....	1.73	− 0.4	7	6,627	se.	38	sw.	28	13	3	12	5.1	9.0	0.3
Kansas City	963	161	181	28.90	29.96	− .15	34.2	+ 4.3	61	11	43	3	28	26	30	30	25	72	2.09	+ 0.5	10	9,055	nw.	42	nw.	14	11	6	11	5.1	13.1	4.0
St. Joseph	967	11	49	28.90	29.96	.....	32.6	.....	61	11	42	2	28	24	39	28	24	76	2.26	.....	12	7,401	nw.	42	nw.	28	13	4	11	5.0	6.2	2.0
Springfield, Mo	1,324	98	104	28.53	29.97	− .14	35.8	+ 2.2	63	24	45	5	9	27	43	31	28	78	2.44	+ 0.2	9	9,063	se.	45	w.	28	15	2	11	4.7	12.7	0.0
Iola	984	11	50	28.87	29.95	− .15	35.1	+ 3.1	61	1	44	4	28	26	30	.....	.....	.....	0.95	− 0.2	8	6,306	s.	29	se.	27	9	6	13	5.8	6.5	2.6
Topeka	983	85	101	.....	.....	.....	33.4	+ 3.4	59	11	42	2	28	24	42	.....	.....	.....	2.13	+ 0.8	11	8,084	se.	39	nw.	14	9	8	11	5.6	9.8	3.0
Drexel	1,299	10	54	28.52	29.95	.....	25.8	.....	59	11	34	− 5	28	18	30	24	22	89	3.01	.....	12	9,107	se.	39	sw.	10	6	10	12	6.4	10.3	0.3
Lincoln	1,189	11	84	28.66	29.97	− .13	27.8	+ 3.0	59	11	36	− 2	28	19	30	25	21	76	2.92	+ 2.2	11	7,254	n.	43	n.	13	6	7	15	6.9	9.0	0.2
Omaha	1,105	115	122	28.76	29.98	− .13	27.8	+ 4.1	61	11	36	− 3	28	20	29	25	21	77	2.07	+ 1.3	11	7,405	nw.	40	nw.	14	4	11	13	6.6	8.5	0.5
Valentine	2,598	47	54	27.19	30.03	− .06	18.5	− 2.7	51	11	27	−16	28	10	35	17	15	90	0.73	+ 0.1	10	6,330	nw.	39	nw.	13	5	11	12	6.1	10.2	0.4
Sioux City	1,135	94	164	28.74	30.01	− .11	23.4	+ 3.6	50	11	31	− 5	28	16	33	21	18	82	2.91	+ 2.4	10	9,042	nw.	41	nw.	28	7	10	11	6.1	13.2	3.5
Huron	1,306	59	74	28.62	30.08	− .04	16.4	+ 3.5	41	10	24	−15	28	8	38	14	11	82	1.10	+ 0.7	10	7,687	se.	42	nw.	13	7	9	12	6.1	11.4	2.8
Pierre	1,572	70	75	28.33	30.09	− .02	14.0	− 2.9	47	10	22	−19	28	6	34	12	9	79	1.29	+ 0.8	9	6,154	nw.	39	nw.	13	4	9	15	7.1	19.5	4.6
Yankton	1,233	49	57	28.64	30.01	− .11	21.4	+ 3.2	49	11	29	−10	28	14	36	.....	.....	.....	2.17	+ 1.6	11	6,541	nw.	36	nw.	13	3	10	15	7.3	12.6	3.5

TABLE I.—*Climatological data for Weather Bureau Stations, February, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								0–10	*In.*	*In.*
Northern Slope.							**21.1**	**− 0.4**										**78**	**1.02**	**+ 0.3**										**6.0**		
Billings	3,140	5	....	....	....	....	23.1	.....	62	9	35	− 8	27	11	51	....	....	....	0.17	.....	5	.....	ne.	....	.....	.....	11	10	7	....	2.2	0.0
Havre	2,505	11	44	27.30	30.05	− .02	14.9	− 0.1	55	9	26	−23	24	4	56	13	10	85	0.97	+ 0.5	10	4,012	e.	30	sw.	10	9	12	7	5.0	9.4	7.3
Helena	4,110	87	114	25.65	29.99	− .12	20.4	− 1.8	51	9	29	−18	24	12	32	17	12	73	1.19	+ 0.7	14	4,316	sw.	36	sw.	9	4	4	20	7.5	12.5	8.4
Kalispell	2,962	11	34	26.79	29.94	− .14	23.0	− 0.8	44	11	31	−17	24	15	41	21	18	81	1.69	+ 0.2	13	3,167	nw.	26	ne.	23	5	3	20	7.8	18.8	11.5
Miles City	2,371	26	48	27.43	30.08	− .01	20.8	+ 4.0	56	11	29	−15	28	12	38	17	14	81	0.82	+ 0.3	9	3,702	ne.	26	n.	10	3	16	9	6.4	6.3	4.1
Rapid City	3,259	50	58	26.50	30.08	.00	19.2	− 4.3	53	11	28	−29	27	10	33	16	10	68	0.55	+ 0.1	7	5,595	n.	36	n.	13	6	8	14	6.5	6.3	1.2
Cheyenne	6,088	84	101	23.79	29.92	− .11	25.6	− 0.7	56	11	36	− 2	3	16	33	21	14	65	0.26	− 0.3	4	10,395	w.	58	w.	22	11	9	8	5.0	2.9	0.2
Lander	5,372	60	68	24.45	29.94	− .14	23.3	+ 1.5	51	11	36	− 4	4	10	38	20	13	64	0.57	− 0.1	7	2,940	sw.	46	sw.	11	10	10	8	4.9	7.5	T.
Sheridan	3,790	10	47	25.97	30.01	.....	21.6	.....	58	9	33	− 6	4	10	47	18	12	72	0.20	.....	....	3,439	nw.	33	nw.	12	8	9	11	5.4	3.0	1.0
Yellowstone Park	6,209	11	48	23.67	29.98	− .12	19.2	− 0.4	40	9	29	− 2	24	10	31	17	13	76	1.64	− 0.2	19	5,390	s.	34	s.	9	3	11	14	7.0	18.2	10.4
North Platte	2,821	11	51	26.99	30.03	− .04	23.6	− 1.0	55	17	34	−11	28	14	43	20	18	84	1.50	+ 1.1	11	5,520	w.	52	nw.	13	13	5	10	4.9	10.1	2.3
Middle Slope.							**33.2**	**+ 0.8**										**76**	**1.34**	**+ 0.8**										**5.4**		
Denver	5,292	106	113	24.53	29.91	− .10	31.1	0.0	61	11	41	8	3	21	39	25	18	63	0.51	0.0	6	5,271	s.	31	nw.	28	12	9	7	4.9	6.5	0.0
Pueblo	4,685	80	86	25.12	29.91	− .09	30.9	− 0.9	65	11	44	1	4	18	42	29	19	68	0.86	+ 0.4	4	4,432	nw.	40	w.	11	10	8	10	5.1	8.8	0.0
Concordia	1,392	50	58	28.46	29.98	− .11	30.9	+ 2.1	60	11	39	− 2	28	23	28	28	26	86	2.36	+ 1.6	11	7,222	nw.	44	nw.	13	6	10	12	6.4	8.9	0.4
Dodge City	2,509	11	51	27.27	29.94	− .12	31.9	+ 0.8	67	11	41	2	27	22	38	27	23	77	1.53	+ 0.8	9	7,850	nw.	48	nw.	13	14	3	11	4.9	10.3	T.
Wichita	1,358	139	158	28.48	29.95	− .13	34.0	+ 1.0	59	11	42	3	28	26	43	28	30	83	2.49	+ 1.4	10	10,478	s.	53	n.	13	8	9	11	5.8	4.2	0.9
Altus	1,410	5	....	....	....	....	42.4	.....	80	11	54	12	28	31	50	....	....	....	1.30	.....	5	.....	n.	....	.....	.....	18	2	8	....	T.	0.0
Muskogee	652	4	....	....	....	....	40.9	.....	65	11	51	9	9	31	44	....	....	....	1.93	.....	9	.....	e.	....	.....	.....	13	6	9	....	3.5	0.0
Oklahoma	1,214	10	47	28.66	29.98	− .09	40.2	+ 1.7	76	11	50	12	28	30	41	34	30	76	1.52	+ 0.5	7	11,364	s.	58	nw.	13	11	6	11	5.4	1.2	0.0
Southern Slope.							**45.4**	**+ 0.8**										**55**	**0.44**	**− 0.4**										**3.9**		
Abilene	1,738	10	52	28.14	29.97	− .08	47.4	+ 2.6	79	11	58	24	9	36	40	38	29	58	0.45	− 0.6	5	8,754	s.	48	sw.	12	11	10	7	4.9	0.1	0.0
Amarillo	3,676	10	49	26.14	29.93	− .09	37.9	+ 0.7	72	11	50	15	25	26	48	31	25	68	0.73	− 0.2	6	8,795	s.	44	nw.	12	14	11	3	4.1	3.7	0.0
Del Rio	944	64	71	28.99	30.00	.00	52.2	− 1.4	74	12	63	29	5	41	36	....	....	....	0.45	− 0.4	6	7,214	se.	56	nw.	12	11	13	4	4.0	0.0	0.0
Roswell	3,506	75	85	26.26	29.89	− .09	44.0	+ 1.5	79	11	58	20	15	30	49	33	16	38	0.15	− 0.4	2	7,466	s.	48	nw.	12	18	9	1	2.5	0.0	0.0
Southern Plateau.							**40.3**	**− 4.6**										**53**	**0.45**	**− 0.1**										**3.4**		
El Paso	3,762	110	133	26.12	29.92	− .03	46.0	− 2.9	74	11	59	24	26	33	40	36	22	41	0.20	− 0.3	3	9,059	w.	62	w.	12	18	9	1	2.6	T.	0.0
Santa Fe	7,013	57	66	23.07	29.94	− .04	27.2	− 4.8	52	11	36	8	4	18	28	23	17	67	0.69	− 0.2	5	6,217	n.	40	nw.	27	14	8	6	4.1	7.6	0.0
Flagstaff	6,908	8	57	23.22	29.96	− .04	20.0	−10.2	46	9	35	−10	4	6	47	19	.....	....	2.17	.....	8	.....	w.	40	sw.	11	14	10	4	....	29.2	7.5
Phoenix	1,108	76	81	28.82	29.99	.00	51.2	− 3.2	74	10	64	32	4	39	35	42	33	57	0.75	+ 0.1	5	3,880	e.	30	w.	11	14	11	3	3.6	0.0	0.0
Yuma	141	9	54	29.85	30.00	.00	55.8	− 3.4	77	10	69	35	2	42	35	45	32	49	T.	− 0.6	0	3,799	w.	33	w.	18	22	6	0	1.6	0.0	0.0
Independence	3,910	11	42	25.92	30.00	− .06	40.8	− 2.9	65	9	52	21	25	30	39	33	23	53	1.13	+ 0.4	6	4,438	nw.	40	se.	10	10	9	9	5.3	2.8	0.0
Needles	488	4	....	29.43	29.98	.....	53.5	.....	73	9	67	33	26	40	....	....	....	....	0.61	.....	4	.....	.....	....	.....	.....	13	3	12	....	.....	.....
Middle Plateau.							**32.9**	**−0.1**										**70**	**1.44**	**+0.3**										**6.7**		
Reno	4,532	74	81	25.38	29.99	− .09	34.8	−0.8	59	8	44	13	3	26	28	31	26	71	3.05	+1.3	8	4,787	w.	37	w.	7	4	12	12	6.9	13.2	T.
Tonopah	6,090	12	20	23.94	29.99	.00	30.0	.....	46	8	37	15	24	23	25	26	21	70	0.40	−0.4	8	7,801	se.	43	se.	10	7	9	12	5.4	5.2	0.0
Winnemucca	4,344	18	56	25.52	29.97	− .12	33.4	+0.1	59	8	41	13	25	26	30	30	26	76	1.52	+0.6	15	5,859	sw.	42	sw.	26	1	6	21	8.5	10.4	T.
Modena	5,479	10	43	24.50	29.94	− .10	29.4	−2.2	53	8	39	6	3	20	31	26	21	69	1.19	0.0	8	7,722	sw.	66	s.	26	10	9	9	5.1	13.1	0.0
Salt Lake City	4,360	163	203	25.52	29.94	− .14	34.2	+1.3	55	11	40	20	25	28	22	30	25	71	2.11	+0.7	17	5,215	nw.	52	nw.	26	1	7	20	8.2	20.2	1.0
Grand Junction	4,602	82	96	25.29	29.92	− .12	32.6	+1.1	59	11	42	11	28	23	27	27	20	63	0.36	−0.3	7	3,788	se.	32	s.	11	7	8	13	6.2	0.7	T.
Northern Plateau.							**34.1**	**+2.0**										**76**	**1.96**	**+0.6**										**8.1**		
Baker	3,471	48	53	26.32	29.96	− .16	29.4	+1.5	47	9	36	11	19	23	21	28	24	80	1.39	0.0	15	4,211	se.	22	se.	9	2	8	18	7.3	11.6	T.
Boise	2,739	78	86	27.09	30.00	− .12	35.8	+2.0	56	9	42	19	3	29	22	32	27	69	1.79	+0.4	16	4,366	se.	30	se.	9	3	5	20	7.9	6.3	0.0
Lewiston	757	40	48	29.13	29.95	− .16	38.4	+2.2	55	15	45	16	24	32	21	....	....	....	1.32	0.0	17	2,585	e.	24	w.	28	1	4	23	8.6	4.5	0.0
Pocatello	4,477	60	68	25.34	29.95	− .15	29.7	+1.6	48	9	36	15	14	24	25	27	23	77	2.06	+1.2	16	8,304	se.	40	sw.	6	0	10	18	8.0	18.0	2.0
Spokane	1,929	101	110	27.85	29.95	− .14	32.2	+2.1	45	9	38	8	24	26	19	30	26	78	3.26	+1.3	20	3,724	sw.	32	sw.	28	1	7	20	8.3	21.9	6.3
Walla Walla	991	57	65	28.87	29.96	− .16	39.0	+2.6	59	9	45	24	3	33	29	35	31	75	1.93	+0.4	16	3,874	s.	32	se.	10	2	4	22	8.4	5.8	0.0
North Pacific Coast Region.							**42.0**	**+0.7**										**84**	**6.02**	**+0.7**										**7.8**		
North Head	211	11	56	29.66	29.90	− .16	43.0	+0.9	53	14	46	34	1	40	18	41	40	90	7.79	+2.0	24	13,469	e.	78	se.	27	1	3	24	8.4	0.0	0.0
North Yakima	1,071	4	....	....	....	.....	35.4	.....	56	28	45	16	2	26	29	....	....	....	1.17	.....	13	.....	nw.	....	.....	.....	6	16	6	....	6.8	0.0
Port Angeles	29	8	53	29.89	29.92	.....	38.9	.....	51	14	45	25	24	33	18	....	....	....	2.93	−0.1	18	3,794	s.	32	nw.	28	5	8	15	6.6	0.3	0.0
Seattle	125	215	250	29.80	29.93	− .13	40.8	+0.3	50	8	45	27	2	36	20	39	36	82	3.77	−0.1	21	6,292	se.	38	s.	28	1	3	24	8.8	T.	0.0
Tacoma	213	113	120	29.69	29.92	− .14	41.0	+0.6	52	8	46	26	1	36	21	39	37	83	3.15	−2.0	21	3,966	sw.	28	sw.	9	1	9	18	8.0	T.	0.0
Tatoosh Island	86	7	57	29.75	29.85	− .15	41.6	+0.6	54	8	45	34	24	38	14	40	37	82	8.06	−0.7	22	12,580	e.	80	sw.	4	4	5	19	7.5	0.3	0.0
Medford	1,425	4	....	....	....	.....	40.5	.....	62	8	48	22	1	33	24	....	....	....	4.30	.....	21	.....	nw.	....	.....	.....	2	2	24	....	T.	0.0
Portland, Oreg	153	68	106	29.78	29.94	− .14	42.6	+1.3	53	15	47	33	2	38	17	40	37	82	8.38	+2.6	22	4,532	se.	30	s.	25	1	8	19	7.9	T.	0.0
Roseburg	510	9	57	29.44	30.00	− .10	43.2	+0.6	66	8	49	29	1	38	20	40	37	82	8.05	+3.5	24	2,404	s.	21	sw.	26	0	12	16	7.6	0.0	0.0
Middle Pacific Coast Region.							**47.6**	**−1.4**										**82**	**5.82**	**+3.0**										**6.8**		
Eureka	62	73	89	30.00	30.06	− .05	47.0	+0.2	62	7	52	32	1	42	20	46	44	89	8.18	+1.2	24	5,939	se.	35	sw.	9	4	4	20	7.7	0.0	0.0
Mount Tamalpais	2,375	11	18	27.55	30.07	− .03	41.3	−4.3	52	7	46	32	23	37	14	39	38	90	10.09	+4.4	22	14,307	nw.	66	s.	10	4	9	15	6.9	T.	0.0
Point Reyes Light	490	7	18	29.53	30.05	.....	48.6	−0.6	56	1	52	40	26	45	14	....	....	....	4.77	.....	23	17,305	nw.	73	nw.	17	5	11	12	6.5	0.0	0.0
Red Bluff	332	50	56	29.08	30.05	− .06	47.0	−2.3	62	15	54	29	3	40	25	44	39	76	5.16	+1.5	18	5,126	se	33	se.	26	4	6	18	7.4	0.0	0.0
Sacramento	69	106	117	30.01	30.08	− .01	48.4	−1.8	61	8	55	33	1	42	20	46	43	81	6.29	+3.2	18	6,330	se	42	se.	26	5	9	14	6.4	0.0	0.0
San Francisco	155	209	213	29.91	30.08	− .02	51.6	+0.3	61	8	57	40	23	46	16	47	43	76	9.31	+5.6	18	5,700	nw.	41	sw.	26	7	9	12	6.2	0.0	0.0
San Jose	141	12	110	29.96	30.11	.....	49.2	−1.4	66	8	58	31	3	41	29	....	....	....	4.87	+2.3	17	5,039	se.	35	se.	10	6	5	17	6.6	0.0	0.0
South Pacific Coast Region.							**51.7**	**−1.1**										**74**	**2.33**	**−0.1**										**5.0**		
Fresno	327	89	98	29.74	30.11	− .02	49.5	+0.3	70	8	58	33	3	41	25	45	39	70	1.36	0.0	9	4,220	nw.	29	s.	10	5	14	9	5.7	T.	0.0
Los Angeles	338	159	191	29.70	30.07	+ .01	53.6	−1.5	73	16	61	41	1	46	24	48	42	70	1.02	−1.9	7	4,621	sw.	29	nw.	27	11	8	9	4.3	T.	0.0
San Diego	87	62	70	29.99	30.09	+ .03	53.6	−1.0	67	16	60	41	25	47	23	49	46	78	1.46	−0.5	13	4,678	w.	34	s.	11	11	8	9	4.7	0.0	0.0
San Luis Obispo	201	32	40	29.90	30.12	− .01	50.2	−2.3	66	16	59	34	4	42	28	46	42	78	5.48	+1.9	14	2,872	nw.	24	se.	10	9	10	9	5.1	0.0	0.0
West Indies.																																		
San Juan, P. R	82	8	54	29.93	30.02	− .03	75.4	.....	89	10	81	65	15	69	20	....	....	....	1.81	−0.7	6	7,033	ne.	44	n.	12	22	5	1	2.4	0.0	0.0
Panama Canal.																																		
Balboa Heights	118	7	97	29.75	29.87	− .01	81.4	+1.1	94	6	89	70	14	74	20	73	71	74	T.	−0.8	0	7,867	n.	32	n.	19	5	23	0	4.8	0.0	0.0
Colon	36	30	97	29.86	29.89	.00	80.1	+0.5	84	26	83	72	14	78	10	75	74	81	0.36	−1.3	10	9,526	n.	28	n.	27	3	15	10	6.5	0.0	0.0
Alaska.																																		
Juneau	80	11	49	.....	.....	.....	30.1	.....	43	20	34	9	28	26	15	27	22	72	3.07	.....	15	3,828	se.	22	ne.	28	7	4	17	7.0	8.1	1.0

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during February, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	21			0.23														0.23			
Albany, N. Y.	14			0.38														0.18			
Alpena, Mich.	28			0.47														*			
Amarillo, Tex.	21			0.32														*			
Anniston, Ala.	22	1:15 a. m.	6:55 a. m.	1.02	6:21 a. m.	6:46 a. m.	0.42	0.12	0.27	0.43	0.51	0.57									
Asheville, N. C.	22			0.91														0.33			
Atlanta, Ga.	22	6:50 a. m.	9:05 a. m.	0.95	8:18 a. m.	8:52 a. m.	0.26	0.11	0.19	0.27	0.31	0.39	0.49	0.55							
Atlantic City, N. J.	14			0.82														0.21			
Augusta, Ga.	25			2.26														0.37			
Baker, Oreg.	4–5			0.38														*			
Baltimore, Md.	14			0.75														0.34			
Bentonville, Ark.	12			0.65														0.25			
Binghamton, N. Y.	14			0.33														0.14			
Birmingham, Ala.	12–13	D. N. a. m.	7:45 a. m.	1.19	4:20 a. m.	4:56 a. m.	0.25	0.07	0.16	0.25	0.28	0.35	0.51	0.64	0.68						
Bismarck, N. Dak.	20–21			0.17														*			
Block Island, R. I.	26			1.20														0.51			
Boise, Idaho.	16–17			0.54														*			
Boston, Mass.	23			0.95														0.26			
Buffalo, N. Y.	13–14			0.43														*			
Burlington, Vt.	14			0.46														*			
Cairo, Ill.	20			0.46														0.17			
Canton, N. Y.	14–15			1.11														*			
Charles City, Iowa.	13			0.95														*			
Charleston, S. C.	25–26	D. N. a. m.	10:00 a. m.	3.52	6:14 a. m.	7:50 a. m.	0.26	0.06	0.11	0.17	0.23	0.28	0.31	0.37	0.42	0.46	0.50	0.67	1.14	1.41	
Charlotte, N. C.	22			1.53														0.36			
Chattanooga, Tenn.	22			1.32														0.45			
Cheyenne, Wyo.	1–2			0.17														*			
Chicago, Ill.	28			0.48														0.25			
Cincinnati, Ohio.	13			0.37														0.16			
Cleveland, Ohio.	28			0.29														*			
Columbia, Mo.	20			0.70														*			
Columbia, S. C.	25			1.12														0.24			
Columbus, Ohio.	28			0.26														0.26			
Concord, N. H.	23			1.00														*			
Concordia, Kans.	1			0.51														0.21			
Corpus Christi, Tex.	17			0.47														0.40			
Dallas, Tex.	1			1.15														0.47			
Davenport, Iowa.	13			0.93														*			
Dayton, Ohio.	13			0.63														0.35			
Del Rio, Tex.	16			0.20														0.06			
Denver, Colo.	19			0.20														*			
Des Moines, Iowa.	13			1.05														0.17			
Detroit, Mich.	13–14			0.43														*			
Devils Lake, N. Dak.	12–13			0.34														*			
Dodge City, Kans.	21–22			0.61														*			
Drexel, Nebr.	13			1.32														0.26			
Dubuque, Iowa.	13			1.21														*			
Duluth, Minn.	2–3			0.48														*			
Eastport, Me.	23			0.83														*			
Elkins, W. Va.	25			0.51														*			
Ellendale, N. Dak.	19–20			0.36														*			
El Paso, Tex.	1			0.17														0.10			
Erie, Pa.	28			0.20														*			
Escanaba, Mich.	13–14			0.70														*			
Eureka, Cal.	8			1.23														0.26			
Evansville, Ind.	20			0.56														0.27			
Flagstaff, Ariz.	1			1.01														*			
Fort Smith, Ark.	12			0.84														0.42			
Fort Wayne, Ind.	13–14			0.50														*			
Fort Worth, Tex.	1			1.31														0.40			
Fresno, Cal.	10			0.26														*			
Galveston, Tex.	1			0.45														0.26			
Grand Haven, Mich.	13–14			0.81														*			
Grand Junction, Colo.	27			0.18														*			
Grand Rapids, Mich.	28			0.49														0.17			
Green Bay, Wis.	13–14			0.64														*			
Greenville, S. C.	28			1.06														0.49			
Hannibal, Mo.	20			0.76														*			
Harrisburg, Pa.	13–14			0.40														*			
Hartford, Conn.	26			0.86														0.25			
Hatteras, N. C.	4			0.80														0.15			
Havre, Mont.	25–26			0.26														*			
Helena, Mont.	28			0.13														*			
Houghton, Mich.	28			0.47														*			
Houston, Tex.	2–3	7:00 p. m.	D. N. a. m.	0.82	8:38 p. m.	8:59 p. m.	0.08	0.13	0.38	0.51	0.59	0.62									
Huron, S. Dak.	19			0.31														*			
Independence, Cal.	26			0.63														*			
Indianapolis, Ind.	28			0.18														0.16			
Iola, Kans.	19			0.20														0.11			
Jacksonville, Fla.	22	3:24 p. m.	7:10 p. m.	1.40	3:42 p. m.	4:38 p. m.	0.04	0.07	0.17	0.23	0.34	0.45	0.57	0.70	0.78	0.88	0.91	1.03			
Kalispell, Mont.	26			0.37														*			
Kansas City, Mo.	12			0.50														0.22			
Keokuk, Iowa.	13			0.67														*			
Key West, Fla.	14			0.45														0.38			
Knoxville, Tenn.	22			0.83														0.34			
La Crosse, Wis.	27–28			0.79														*			
Lander, Wyo.	12			0.26														*			
Lansing, Mich.	13–14			0.43														*			
Lewiston, Idaho.	16			0.38														0.09			
Lexington, Ky.	25			0.43														0.17			
Lincoln, Nebr.	12–13			1.90														*			
Little Rock, Ark.	12			1.25														0.54			
Los Angeles, Cal.	26			0.21														0.12			
Louisville, Ky.	20			0.36														0.20			
Ludington, Mich.	13			0.48														0.21			
Lynchburg, Va.	28			0.29														0.16			
Macon, Ga.	25			4.67														0.75			
Madison, Wis.	13–14			1.06														*			
Marquette, Mich.	28			0.70														*			
Memphis, Tenn.	20			0.49														0.26			
Meridian, Miss.	13			1.00														0.64			

* Self-register not in use.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during February, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Miami, Fla.	2			1.99														0.69			
Milwaukee, Wis.	13–14			0.82														*			
Minneapolis, Minn.	2–3			0.80														*			
Mobile, Ala.	22	D. N. a. m.	5:40 a. m.	1.37	4:08 a. m.	4:52 a. m.	0.07	0.29	0.87	0.95	0.98	1.00	1.03	1.10	1.18	1.29					
Modena, Utah.	17–18			0.49														*			
Montgomery, Ala.	13	7:15 a. m.	11:05 a. m.	1.20	7:49 a. m.	5:09 a. m.	0.02	0.14	0.33	0.50	0.73										
	24–25	5:10 p. m.	D. N. p. m.	5.26	11:12 p. m.	12:02 a. m.	0.85	0.08	0.14	0.24	0.30	0.44	0.55	0.65	0.71	0.75	0.80				
					12:02 a. m.	12:52 a. m.	.....	0.88	0.93	1.98	1.03	1.16	1.22	1.34	1.38	1.40	1.42				
					12:52 a. m.	1:16 a. m.	.....	1.44	1.52	1.67	1.77	1.86									
Moorhead, Minn.	24			0.22														*			
Mount Tamalpais, Cali.	11			0.88														0.36			
Nantucket, Mass.	23			0.36														0.21			
Nashville, Tenn.	20			0.58														0.29			
New Haven, Conn.	25–26			1.44														*			
New Orleans, La.	25			1.56														0.53			
New York, N. Y.	25–26			1.28														0.28			
Norfolk, Va.	4			0.71														0.16			
Northfield, Vt.	14			0.55														*			
North Head, Wash.	25			1.15														0.19			
North Platte, Nebr.	1–2			0.53														*			
Oklahoma, Okla.	1			0.39														0.17			
Omaha, Nebr.	12–13			1.09														*			
Oswego, N. Y.	13–14			0.28														*			
Palestine, Tex.	1			0.74														0.28			
Parkersburg, W. Va.	28			0.43														0.23			
Pensacola, Fla.	13	8:18 a. m.	9:50 a. m.	0.68	8:39 a. m.	8:59 a. m.	0.09	0.27	0.45	0.50	0.56										
	20	7:50 p. m.	4:30 p. m.	3.88	12:41 p. m.	1:11 p. m.	2.10	0.17	0.29	0.32	0.38										
					3:11 p. m.	3:27 p. m.	3.28	0.15	0.37	0.47	0.53	0.58	0.69								
	22	5:40 a. m.	7:45 a. m.	1.20	6:31 a. m.	6:58 a. m.	0.04	0.06	0.28	0.54	0.78	0.96	1.06								
	25	6:25 a. m.	7:05 p. m.	3.00	11:56 a. m.	1:51 p. m.	0.44	0.06	0.22	0.40	0.57	0.66	0.69	0.71	0.77	0.88	0.91	0.94	1.17	1.57	1.77
Peoria, Ill.	28			0.49														0.24			
Philadelphia, Pa.	25–26			1.13														0.37			
Phoenix, Ariz.	1			0.42														0.15			
Pierre, S. Dak.	20			0.44														*			
Pittsburgh, Pa.	28			0.30														0.27			
Pocatello, Idaho.	11–12			0.82														*			
Point Reyes Light, Cal.	9			0.54														0.26			
Port Angeles, Wash.	12			0.19														0.18			
Port Huron, Mich.	13–14			0.60														*			
Portland, Me.	23			1.17														0.18			
Portland, Oreg.	8			1.80														0.23			
Providence, R. I.	23			0.96														*			
Pueblo, Colo.	19			0.43														*			
Raleigh, N. C.	22			0.94														0.19			
Rapid City, S. Dak.	2			0.26														*			
Reading, Pa.	14			1.18														0.30			
Red Bluff, Cal.	10			1.50														0.30			
Reno, Nev.	10–11			1.47														*			
Richmond, Va.	13–14			0.86														0.17			
Rochester, N. Y.	13–14			0.42														*			
Roseburg, Oreg.	8–9			1.87														0.26			
Roswell, N. Mex.	1			0.12														0.10			
Sacramento, Cal.	6–7			0.40														0.24			
Saginaw, Mich.	28			0.52														0.41			
St. Joseph, Mo.	3			0.44														0.19			
St. Louis, Mo.	20			0.42														0.12			
St. Paul, Minn.	13–14			0.72														*			
Salt Lake City, Utah.	11–12			0.58														*			
San Antonio, Tex.	16–17			0.66														*			
San Diego, Cal.	11			0.45														0.22			
Sandusky, Ohio.	28			0.28														0.22			
Sandy Hook, N. J.	26			0.54														0.35			
San Francisco, Cal.	10			2.86														0.54			
San Jose, Cal.	26			1.05														0.22			
San Luis Obispo, Cal.	10			1.94														0.35			
Santa Fe, N. Mex.	18–19			0.31														*			
Sault Ste. Marie, Mich.	24–25			0.37														*			
Savannah, Ga.	25			2.66														0.47			
Scranton, Pa.	13–14			0.56														*			
Seattle, Wash.	11			0.29														0.11			
Sheridan, Wyo.	27			0.06														*			
Shreveport, La.	19			0.74														0.44			
Sioux City, Iowa.	13			1.38														*			
Spokane, Wash.	24–25			0.96														*			
Springfield, Ill.	20			0.56														*			
Springfield, Mo.	22			0.63														*			
Syracuse, N. Y.	14			0.50														*			
Tacoma, Wash.	8			0.68														0.10			
Tampa, Fla.	13–14	D. N. p. m.	D. N. a. m.	1.07	12:53 a. m.	1:27 a. m.	0.05	0.09	0.25	0.28	0.45	0.69	0.87	0.91							
Tatoosh Island, Wash.	14			0.99														0.29			
Taylor, Tex.	19			0.82														0.57			
Terre Haute, Ind.	13–14			0.50														*			
Thomasville, Ga.	22	11:26 a. m.	2:05 p. m.	1.01	11:55 a. m.	12:10 p. m.	0.03	0.15	0.38	0.62											
	25–26	7:35 a. m.	D. N. a. m.	2.71	5:37 p. m.	6:10 p. m.	0.74	0.11	0.16	0.43	0.46	0.56	0.68	0.77							
Toledo, Ohio.	28			0.32														*			
Tonopah, Nev.	2–3			0.09														*			
Topeka, Kans.	3			0.22														0.15			
Trenton, N. J.	23			0.58														0.26			
Valentine, Nebr.	1–2			0.35														*			
Vicksburg, Miss.	21			0.48														0.31			
Walla Walla, Wash.	16–17			0.72														*			
Washington, D. C.	14			0.39														0.13			
Wausau, Wis.	28			0.67														*			
Wichita, Kans.	2			1.28														*			
Williston, N. Dak.	12–13			0.60														*			
Wilmington, N. C.	13			0.29														0.22			
Winnemucca, Nev.	22			0.31														0.11			
Wytheville, Va.	22			0.35														0.17			
Yankton, S. Dak.	12–13			1.23														*			
Yellowstone Park, Wyo.	10–11			0.35														*			

* Self-register not in use.

TABLE III.—*Data furnished by the Canadian Meteorological Service, February, 1919.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.25	29.39	−.46	27.0	+5.0	32.0	22.0	40	8	3.17	−1.74	16.0
Sydney, C. B. I.	48	29.62	29.66	−.26	26.0	+6.7	32.3	19.8	42	8	2.85	−1.24	25.5
Halifax, N. S.	88	29.62	29.73	−.22	27.1	+4.7	33.0	21.2	41	9	1.94	−3.22	10.0
Yarmouth, N. S.	65	29.70	29.77	−.22	29.1	+3.3	33.3	24.9	41	15	2.76	−1.98	1.4
Charlottetown, P. E. I.	38	29.66	29.70	−.25	24.0	+6.4	29.2	18.7	35	8	2.21	−0.85	22.1
Chatham, N. B.	28	29.75	29.78	−.18	23.1	+10.8	31.7	14.5	38	−6	2.08	−1.08	20.8
Father Point, Que.	20	29.84	29.87	−.11	18.2	+6.7	25.7	10.7	36	−10	2.05	−0.16	20.5
Quebec, Que.	296	29.58	29.92	−.07	17.4	+5.6	25.4	9.5	33	−8	1.96	−1.31	19.6
Montreal, Que.	187	29.74	29.96	−.06	20.1	+5.6	25.5	14.7	35	6	2.02	−1.05	18.6
Stonecliffe, Ont.	489	29.34	29.98	−.03	11.7	+1.8	27.3	−3.8	38	−22	1.02	−0.98	9.8
Ottawa, Ont.	236	29.71	29.99	−.03	19.3	+7.6	28.8	9.8	37	−7	1.57	−1.12	15.4
Kingston, Ont.	285	29.67	29.99	−.05	25.8	+8.0	33.5	18.2	46	8	1.41	−1.13	4.0
Toronto, Ont.	379	29.56	29.99	−.05	28.3	+6.8	34.9	21.7	53	10	1.81	−0.80	5.0
Cochrane, Ont.	930	.....	.....	.....	11.5	.....	20.9	2.2	36	−20	1.60	.....	16.0
White River, Ont.	1,244	28.57	29.94	−.08	11.3	+11.1	23.0	−0.3	42	−31	0.65	−0.87	5.9
Port Stanley, Ont.	592	29.32	29.98	−.08	27.5	+4.7	34.3	20.8	43	10	1.94	−1.27	6.8
Southampton, Ont.	656	29.24	.....	.....	25.2	+5.3	31.0	19.5	45	1	1.91	−0.99	8.2
Parry Sound, Ont.	688	29.26	29.99	−.02	20.3	+6.0	29.3	11.3	43	−9	3.30	+0.38	33.0
Port Arthur, Ont.	644	29.26	29.99	−.06	16.8	+10.4	25.8	7.9	37	−20	0.85	−0.05	8.5
Winnipeg, Man.	760	29.23	30.12	+.02	4.0	+5.6	12.1	−4.0	30	−30	0.45	−0.53	4.5
Minnedosa, Man.	1,690	28.19	30.13	+.04	0.1	+2.8	11.2	−11.0	36	−41	0.49	−0.12	4.9
Le Pas, Man.	860	.....	.....	.....	−3.2	.....	7.2	−13.6	28	−40	0.07	.....	0.7
Qu'Appelle, Sask.	2,115	27.71	30.11	+.03	−1.1	+0.5	9.2	−11.4	39	−50	1.38	+0.65	13.8
Medicine Hat, Alb.	2,144	27.63	30.02	−.03	14.3	+3.1	24.8	3.8	56	−25	0.35	−0.32	3.5
Moose Jaw, Sask.	1,759	.....	.....	.....	2.6	.....	12.8	−7.5	43	−33	1.25	.....	12.5
Swift Current, Sask.	2,392	27.23	29.99	−.08	7.2	−.08	16.3	−1.9	42	−31	1.60	+0.86	16.0
Calgary, Alb.	3,428	26.30	29.99	.00	15.0	+1.5	25.3	4.8	54	−23	1.12	+0.49	11.2
Banff, Alb.	4,521	25.21	30.01	+.03	10.0	−9.2	21.3	−1.3	39	−31	0.85	−0.07	8.5
Edmonton, Alb.	2,150	27.64	30.05	+.03	6.1	−2.2	16.5	−4.3	43	−37	0.54	−0.13	5.4
Prince Albert, Sask.	1,450	28.49	30.14	+.05	0.8	+3.8	11.2	9.6	34	−46	0.16	−0.53	1.6
Battleford, Sask.	1,592	28.28	30.13	+.04	1.0	+0.9	11.1	−9.0	35	−50	0.30	−0.07	3.0
Kamloops, B. C.	1,262	28.09	30.02	+.06	26.5	−1.8	32.9	20.1	47	0	0.98	+0.19	8.5
Victoria, B. C.	230	29.62	29.88	−.12	40.1	+0.6	44.5	35.6	51	27	2.75	−1.35	0.1
Barkerville, B. C.	4,180	25.48	29.92	+.01	14.3	−4.6	23.0	5.7	41	−21	0.57	−2.49	5.7
Triangle Island, B. C.	680	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Prince Rupert, B. C.	170	.....	.....	.....	34.4	.....	39.4	29.4	48	6	7.05	.....	9.2
Hamilton, Ber.	151	29.81	29.98	−.13	55.4	−6.1	64.9	54.9	70	47	3.60	−0.84	0.0

SEISMOLOGY.*

SEISMOLOGICAL REPORTS FOR FEBRUARY, 1919.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Mar. 1, 1919.]

TABLE 1.—*Noninstrumental earthquake reports, February, 1919.*

Day.	Approximate time. Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
	H. m.		° ′	° ′			*Seconds.*			
Feb. 9	15 57	San Pedro	32 45	118 14	2	1		None		Geo. Linder.
10	24 00	Bishop	32 22	118 24	5	1		None		Associated Press.
14	22 47	Calexico	32 41	115 30	2	1	0.1	None		H. M. Rouse.
16	15 58	Bakersfield	35 22	119 00	4-5	3		Rumbling	Awakened people	F. W. Warthorst.
		Fairmont	34 15	118 25	5	1	10	Rumbling	Small bells rung	Wm. F. C. Lowe.
		Glennville	35 45	118 42	4	2	5	Rumbling	Sounds with second shock	C. H. Likely.
		Lindsay	36 13	119 06	3-4	1	5	Rattling		Basil Prior.
		Los Angeles	34 03	118 15	5	1		Rumbling	Some clocks stopped	R. A. Nelson.
		Maricopa	35 05	119 08	5	1	20	Rumbling		E. F. Foulke.
		Ojai	34 25	119 12	5	1	3	Faint		W. H. Duncan.
		San Luis Obispo	35 18	120 39	4	1	30	None		J. E. Hissong.
		San Pedro	33 45	118 14	4	1		None		Geo. Linder.
		Santa Barbara	34 23	119 40	5	1		None		Associated Press.
		Springville	36 07	118 50		1	2	Rumbling		Mary Birkhead.
17	20 00	Maricopa	35 05	119 08	2	1	10	Faint		E. F. Foulke.
19	3 52	Amos	33 05	115 16	2		30	None		A. W. Sullivan.
		Barrett	32 43	116 46	4	1	3	None		L. Watts.
		Calexico	32 41	115 30	3	1	3	None		H. M. Rouse.
19	4 03	Calexico	32 41	115 30	2	1	30	None		H. M. Rouse.
19	4 55	Barrett	32 43	116 46	5	1	3	None		L. Watts.
		Brawley	32 59	115 40	4	3			Mud volcanoes active	M. D. Witter.
		Calexico	32 41	115 30	4	3	17	Rumbling	Sharp lurch, direction noticed	H. M. Rouse.
19	5 30	Amos	33 05	115 16	2		30	None		A. W. Sullivan.
19	13 23	Calexico	32 41	115 30	4	1	30	Rumbling	Several lighter shocks	H. M. Rouse.
20	3 59	Calexico	32 41	115 30	4	1	33	Rumbling		H. M. Rouse.
		Imperial	32 50	115 35	4	1		None		Associated Press.
20	8 50	Lone Pine	36 37	118 01	4	4		Rattling		G. F. Marsh.
25	22 39	Berkeley	37 52	122 16	3	1		None	Felt by persons at rest	Dr. E. F. Davis.
		Napa	38 18	122 20	5-6	3	5	Rumbling	Some bells rung	G. A. Lewis.
		Oakland	37 48	122 15	5	1		None		Emma Smith.
		Peachland	38 23	122 48	4	1	2			F. H. Parnell.
		Petaluma	38 15	122 38	5	1	15	Rumbling	Some alarm	John Landis.
		Point Reyes	38 02	122 59	5	1	10	Rumbling		Mrs. John Kelly.
		San Francisco	37 48	122 26	3	1	4	None	Shook objects in tall buildings	U. S. Weather Bureau.
27	19 18	Calexico	32 41	115 30	2	1	5	None		H. M. Rouse.
		NEW MEXICO.								
1	4 30	Socorro	34 08	106 48	4-5		20	Rumbling	Followed by 3 shocks	J. J. Leeson.
1	20 30	Socorro	34 08	106 48	5		30	Rumbling	Some alarm	J. J. Leeson.

*For explanation of abbreviations used in the following tables, see this REVIEW, January, 1919, p. 59.

THE NEW SEISMOGRAPHS AT THE UNIVERSITY OF CHICAGO.

Two Milne-Shaw seismographs, one registering the east-west component the other the north-south component, have recently been installed by the Weather Bureau in Rosenwald Hall of the University of Chicago, the records from which for the months of January and February, 1919, together with the constants of the instruments appear in this number of the REVIEW. The horizontal pendulum of each instrument carries a "steady" mass of only 454 grams. The registration is photographic and is obtained by means of a simple but effective optical train that includes a delicately balanced rotating mirror. The concrete pier upon which the instruments are mounted rests upon bed rock 62′ 10″ below the level of the floor of the seismograph room. While some difficulty is experienced on account of the location, both as to tilting and wind disturbances, the records are for the most part excellent. The machines are maintained and operated by the Weather Bureau in cooperation with the University of Chicago.

The Milne-Shaw seismograph is described in detail in a Handbook on the instrument by the maker J. J. Shaw, West Bromwich, England, and, briefly, in the Report of the British Association for the Advancement of Science for 1915, page 57.—R. H. FINCH.

TABLE 2.—*Instrumental seismological reports, February, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(Nothing worth recording during January and February, 1919.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	17
	N	10	15

(No earthquake recorded during February, 1919.)

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 709.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	14
	N	10	18

1919.			H. m. s.	Sec.	μ	μ	km.	
Feb. 16	.....	P_N	16 01 39	.....	.....	.....	.....	Poor record.
	.....	P_E	16 01 39	.....	.....	.....	.....	
	.....	M_E	16 02 —	.....	.....	.....	.....	
		F_N	16 02 —	.....	.....	.....	.....	
		F_E	16 04 —	.....	.....	.....	.....	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

1919.			H. m. s.	Sec.	μ	μ	km.	
Feb. 4	.....	.....	.....	.....	*100	*200	.....	Tremors during 24 hours preceding 16h 00m on dates given.
7	.....	.....	.....	.....	*50	*100	.....	
15	.....	.....	.....	.....	*200	*150	.....	
17	.....	.....	.....	.....	*200	*200	.....	

*Amplitude on instrument.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A.W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80-kg., astatic, horizontal pendulum.

Instrumental constants .....

(No earthquake recorded during February, 1919.)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

Instrumental constants..	V	T_0
	110	6.4

1919.			H. m. s.	Sec.	μ	μ	km.	
Feb. 2	.....	e	20 18 33	.....	.....	.....	.....	
		L	20 27 40	.....	.....	.....	.....	
		F	20 40 ..	.....	.....	.....	.....	
16	.....	e	16 14 47	.....	.....	.....	.....	
		F	16 25 ..	.....	.....	.....	.....	

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants..		V	T_0	e
	E	165	5.4	0
	N	143	5.2	0
	Z	*80*	*3.0*	*0*

1919.			H. m. s.	Sec.	μ	μ	km.	
Feb. 2	.....	e_E?	20 17 07	.....	.....	.....	.....	Microseisms.
		e_{LE}	20 25 24	22	.....	.....	.....	
		L_E	20 29 07	22	.....	.....	.....	
		L_N	20 29 56	22	.....	.....	.....	
		F	20 50 ..	.....	.....	.....	.....	
16	.....	e	16 15 28	.....	.....	.....	.....	Heavy microseisms.
		eL_E	16 18 30	11	.....	.....	.....	
		F	16 35 ..	.....	.....	.....	.....	

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant..T_0 18.1. Sensitiveness 0.40 arc tilt=1 mm.

1919.			H. m. s.	Sec.	μ	μ	km.	
Feb. 5	.....	P	20 22 00	18	.....	.....	.....	
		L	20 29 30	24	.....	.....	.....	
		M	20 38 30	19	*200	.....	.....	
		C	20 43 ..	19	.....	.....	.....	
		F	21 03 ..	.....	.....	.....	.....	
9	.....	P	13 03 24	18	.....	.....	.....	
		eL	13 15 30	.....	.....	.....	.....	
		M	13 20 ..	16	*100	.....	.....	
		F	13 43 ..	19	.....	.....	.....	
9	.....	P	15 43 36	19	.....	.....	.....	
		L	15 56 00	22	.....	.....	.....	
		M	16 00 30	20	*100	.....	.....	
		F	16 09 ..	.....	.....	.....	.....	
12	.....	P	12 57 54	18	.....	.....	.....	The waves beginning at 13h 05m die out before the swell to maximum.
		eL	13 05 ..	.....	.....	.....	.....	
		M	13 11 12	15	*400	.....	.....	
		C	13 35 ..	18	.....	.....	.....	
		F	13 53 ..	18	.....	.....	.....	
12	.....	P	21 03 42	19	.....	.....	.....	
		eL	21 11 ..	25	.....	.....	.....	
		M	21 18 00	15	*300	.....	.....	
		C	21 25 ..	.....	.....	.....	.....	
		F	21 48 ..	19	.....	.....	.....	
22	.....	P	4 32 42	18	.....	.....	.....	
		L	4 39 48	22	.....	.....	.....	
		M	4 47 00	17	*200	.....	.....	
		C	5 01 ..	18	.....	.....	.....	
		F	5 34 ..	18	.....	.....	.....	

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, February, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Illinois. *Chicago.* University of Chicago. U. S. Weather Bureau. Lat., 41° 47′ N.; long., 87° 37′ W. Elevation, 180.1 meters. Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg. Instrumental constants.. E: V 150, T_0 12, e 20:1, Sensitivity. 1″arc tilt=26.6 mm. N: V 150, T_0 8, e 20:1, Sensitivity. 1″arc tilt=13.2 mm.								
1919. Feb. 2	.....	P.....	*H. m. s.* 20 13 30	*Sec.*	.....	.....	*km.* 3,470	
		S.....	20 18 45	.....	.....	.....	.....	
		L.....	20 22 35	16	.....	.....	.....	
		L.....	20 27 00	20	.....	.....	.....	
		L.....	20 29 ..	16	.....	.....	.....	
		F.....	21 20 ..	.....	.....	.....	.....	
15	.....	P.....	2 31 00	.....	.....	.....	3,965	
		S.....	2 36 45	.....	.....	.....	.....	
		L.....	2 40 00	.....	.....	.....	.....	
		L.....	2 43 ..	15	.....	.....	.....	
		F.....	3 30 ..	.....	.....	.....	.....	
16	.....	P?.....	16 06 05	.....	.....	.....	3,170	
		S.....	16 11 00	.....	.....	.....	.....	
		L.....	16 18 00	.....	.....	.....	.....	
		F.....	16 35 ..	.....	.....	.....	.....	
22	.....	S?.....	4 38 08	.....	.....	.....	.....	
		L?.....	4 45 00	.....	.....	.....	.....	
		F.....	5 30 ..	.....	.....	.....	.....	
Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester. Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters. Instrument: Wiechert. Instrumental constants.. E: V 177, T_0 3.4, e 4:1. N: V 205, T_0 3.4, e 4:1. (Report for February, 1919, not received.)								
Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell. Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters. Instruments: Two Bosch-Omori, 10 and 12 kg. Instrumental constants.. E: V 10, T_0 15. N: V 10, T_0 15.								
1919 Feb. 1	.....	e_E.....	*H. m. s.* 0 02 20	*Sec.* 7	.....	.....	*km.*	[Probably part of quake that had its beginning on Jan. 31st.]
		e_N.....	0 02 49	.....	.....	.....	.....	
		M_N.....	0 06 ..	9	.....	20	.....	
		M_E.....	0 07 ..	10	20	.....	.....	
		F_E.....	0 22 ..	7	.....	.....	.....	
		F_N.....	0 28 ..	8	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Massachusetts. *Cambridge. Harvard University Seismographic Station,* J. B. Woodworth. Lat., 42° 22′ 35″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay. Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration). Instrumental constants— E: V 80, T_0 23, e 0. N: V 50, T_0 25, e 4:1								
1919. Jan. 31	.....	*O*?....	*H. m. s.* *23 53 34*	*Sec.*	.....	.....	*km.* 2,357	P masked by microseisms.
Feb. 1	.....	S_N....	0 02 20	6	.....	.....	.....	E–W damped 1½: 1 by magnet operating automatic alarm during M of heavy earthquakes.
		eL_N...	0 03 54	20	.....	.....	.....	
		M_N....	0 05 32	10	.....	.....	.....	
		F_N?...	0 35 44	.....	.....	.....	.....	
2	.....	*O*.....	*19*	.....	.....	.....	.....	Phases before L 21h 25m 41s much distorted by microseisms.
		e_E....	20 06 23	8	.....	.....	.....	
		i_N.....	20 06 38	.....	.....	.....	.....	
		e_E....	20 15 21	6	.....	.....	.....	
		e_N.....	20 17 35	12	.....	.....	.....	
		e_E....	20 17 56	10	.....	.....	.....	
		L_E?...	20 25 06	20	.....	.....	.....	
		L_E....	20 25 32	28	.....	.....	.....	
		L_E....	20 26 31	16	.....	.....	.....	
		F_E....	20 50 ..	.....	.....	.....	.....	
12	.....	L?.....	13 25 51	18	.....	.....	.....	e masked by microseisms.
		L_N....	13 32 20	20	.....	.....	.....	
		L.....	13 27 21	15	.....	.....	.....	
		F?.....	13 55 ..	.....	.....	.....	.....	
15	.....	*O*.....	*2*	.....	.....	.....	.....	
		e_N.....	2 31 22	.....	.....	.....	.....	
		e.....	2 31 29	6	.....	.....	.....	
		e_E....	2 34 59	5	.....	.....	.....	
		L_E....	2 37 49	20	.....	.....	.....	
		L_N....	2 38 03	.....	.....	.....	.....	
		L_E....	2 40 25	17	.....	.....	.....	
		L_N....	2 42 45	12	.....	.....	.....	
		F_E....	2 53 03	.....	.....	.....	.....	
16	.....	i_E.....	16 20 21	.....	.....	.....	.....	Cf. Ottawa e 16h 16m 18s.
		L_E....	16 20 35	8	.....	.....	.....	N–S time line tangled by heavy cyclonic tilt of pendulum to north for previous 24 hours.
		L_E....	16 20 43	9	.....	.....	.....	
		F?.....	16 20 52	.....	.....	.....	.....	
22	.....	*O*.....	4	.....	.....	.....	.....	Rather weak record on both components.
		e_N?....	5 00 03	6	.....	.....	.....	
		L_E....	5 04 22	22	.....	.....	.....	
		L_E....	5 08 13	14	.....	.....	.....	
		M_N?...	5 12 45 / 5 17 09	14–16	.....	.....	.....	
		F_N?...	5 30 ..	.....	.....	.....	.....	
Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J. Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick. Instrument: Wiechert 80 kg. astatic, horizontal pendulum. Instrumental constants.. V 80, T_0 7, e 5:1. (Report for February, 1919, not received.)								
New York. *Ithaca. Cornell University.* Heinrich Ries. Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters. Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration). Instrumental constants.. E: V 13, T_0 22, e 4:1. N: V 14, T_0 25, e 4:1								
1919. Feb. 1...	.....	eL....	*H. m. s.* 0 02 48	*Sec.* 12	.....	.....	*km.*	[Probably part of the quake beginning on Jan. 31.] Early phases lost in microseisms.
		F.....	0 16 ..	.....	.....	.....	.....	
2...	.....	eL....	20 25 33	15	.....	.....	.....	
		F.....	20 36 ..	.....	.....	.....	.....	
15...	.....	eL....	2 4. 30	16	.....	.....	.....	
		F.....	2 46 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, February, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
New York. *New York. Fordham University.* W. C. Repetti, S. J.								
Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.								
Instrument: Wiechert, 80 kg.								
			V	T_0	ε			
Instrumental constants..			E	72	5.0	0		
			N	72	5.0	0		
(Report for February, 1919, not received.)								
Panama Canal. *Balboa Heights.* Governor, Panama Canal.								
Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.								
Instruments: Two Bosch-Omori, 25 kg.								
				V	T_0			
Instrumental constants. .				10	20			
1919. Feb. 10	.....	P_N	H. m. s. 10 45 36	Sec.	μ	μ	km. 295	Direction uncertain.
		P_E	10 45 42	.....	.....	.....	.....	
		L_N	10 46 06	.....	.....	.....	.....	
		L_E	10 46 20	.....	.....	.....	.....	
		M_E	10 46 52	.....	*4,100	.....	.....	
		M_N	10 46 58	.....	.....	*800	.....	
		F_N	10 53 00	.....	.....	.....	.....	
		F_E	10 54 00	.....	.....	.....	.....	
*Trace amplitude.								
Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.								
Lat., 18° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.								
Instruments: Two Bosch-Omori.								
				V	T_0			
Instrumental constants..			E	10	18			
			N	10	20			
(No earthquake recorded during February, 1919.)								
Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.								
Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.								
Instruments: Two Bosch-Omori, mechanical registration.								
				V	T_0			
Instrumental constants..			E	10	15			
			N	10	16			
1919. Feb. 2	.....	eL	H. m. s. 20 26 00	Sec.	μ	μ	km.	
		F	20 35 ..	.....	.....	.....	.....	
Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.								
Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.								
Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80k. vertical seismograph.								
				V	T_0			
Instrumental constants..				120	26			
1919. Feb. 1	.....	e	H. m. s. 0 00 40	Sec.	μ	μ	km.	Heavy microseisms. [Probably part of quake that had its beginning on Jan. 31.]
		L	0 01 30	14	.....	.....	.....	
		L	0 15 ..	8	.....	.....	.....	
		F	0 20 ..	.....	.....	.....	.....	
2	.....	e	20 17 12	.....	.....	.....	.....	
		e	20 20 ..	12	.....	.....	.....	
		eL	20 24 ..	20	.....	.....	.....	
		L	20 36 ..	12	.....	.....	.....	
		F	20 45 ..	.....	.....	.....	.....	
15	.....	e_N?	2 31 ..	.....	.....	.....	.....	
		e	2 34 36	.....	.....	.....	.....	
		eL	2 38 .. / 2 43 ..	20	.....	.....	.....	
		L	2 45 ..	12	.....	.....	.....	
		F	2 55 ..	.....	.....	.....	.....	
16	.....	e_E	16 16 16	.....	.....	.....	.....	
		L	16 16 39	7	.....	.....	.....	
		F	16 21 ..	.....	.....	.....	.....	
22	.....	e	5 00 ..	.....	.....	.....	.....	
		eL?	5 06 ..	20	.....	.....	.....	
		L	5 11 ..	18	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Canada. *Toronto. Dominion Meteorological Service.*								
Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.								
Instrument: Milne horizontal pendulum, North; in the meridian.								
				T_0				
Instrumental constant..				18.				
Pillar deviation, 1 mm. swing of boom=0.50″.								
1919. Feb. 2	.....	e	H. m. s. 20 20 48	Sec.	μ	μ	km.	Microseisms make early phases doubtful.
		S	20 24 24	.....	.....	.....	.....	
		eL	20 26 48	.....	.....	.....	.....	
		M	20 28 24	.....	*1,400	.....	.....	F lost in microseisms.
12	.....	L?	13 24 54?	.....	.....	.....	.....	Microseisms going on.
		M	13 35 30	.....	*300	.....	.....	F in microseisms.
15	.....	eL	2 39 18	.....	.....	.....	.....	Marked gradual thickening.
		M	2 42 24	.....	*600	.....	.....	
		F	3 00 00?	.....	.....	.....	.....	
16	.....	L?	16 07 00?	.....	*200	.....	.....	Small microseisms going on.
		F	16 12 00?	.....	.....	.....	.....	
22	.....	L	4 58 54?	.....	.....	.....	.....	Small microseisms going on. F in microseisms.
		L	5 10 12	.....	.....	.....	.....	
*Trace amplitude.								
Canada. *Victoria, B. C. Dominion Meteorological Service.*								
Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.								
Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.								
				T_0				
Instrumental constant..				18.				
Pillar deviation, 1 mm. swing of boom=0.54″.								
1919. Feb. 2	.....	P	H. m. s. 20 24 27?	Sec.	μ	μ	km.	
		L	20 29 22?	.....	.....	.....	.....	
		M	20 31 49	.....	*200	.....	.....	
		F	20 45 35	.....	.....	.....	.....	
12	.....	P	12 59 32?	.....	.....	.....	.....	
		M	13 28 33	.....	*300	.....	.....	
		F	14 06 59	.....	.....	.....	.....	
16	.....	P	16 05 38?	.....	.....	.....	.....	
		L	16 07 07	.....	.....	.....	.....	
		M	16 09 06	.....	*200	.....	.....	
		F	16 14 33	.....	.....	.....	.....	
22	.....	P	4 51 17?	.....	.....	.....	.....	F?
		M	4 56 42	.....	*100	.....	.....	
*Trace amplitude.								

TABLE 2.—*Instrumental seismological reports, February, 1919*—Contd.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

TABLE 3.—*Late reports (instrumental).*

Illinois. *Chicago.* University of Chicago. U. S. Weather Bureau.

Lat., 41° 47′ N.; long., 87° 37′ W. Elevation, 180.4 meters.

Instruments: Two Milne-Shaw horizontal pendulums, .45 kg.

Instrumental constants..		V	T_0	ε	Sensitivity.
	E	150	12	20:1	1″ arc tilt=26.6 mm.
	N	150	8	20:1	1″ arc tilt=13.2 mm.

1919.			H. m. s.	Sec.	μ	μ	km.	
Jan. 1	.....	P.....	1 54 13	.....	.....	.....	8,345	Beginning of L not well defined.
		S.....	2 03 50	.....	.....	.....	.....	
		L.....	2 24 00	20	.....	.....	.....	Record merges into next quake.
		L.....	2 47 00	16	.....	.....	.....	
1	.....	P.....	3 1ɔ 27	.....	.....	.....	5,390	
		S.....	3 22 30	.....	.....	.....	.....	
		L.....	3 29 00	30	.....	.....	.....	Beginning of L not well defined.
		F.....	6 40 ..	.....	.....	.....	.....	
Jan. 5	.....	P.....	20 12 19	.....	.....	.....	6,550	
		S.....	20 20 25	.....	.....	.....	.....	
		L.....	20 35 30	.....	.....	.....	.....	
		L.....	20 38 20	20	.....	.....	.....	
		F.....	21 10 ..	.....	.....	.....	.....	
6	.....	e.....	23 17 00	.....	.....	.....	.....	P and S doubtful.
		L.....	23 21 00	25	.....	.....	.....	
		L.....	23 25 00	19	.....	.....	.....	
		L.....	23 31 00	16	.....	.....	.....	
7	.....	F.....	1 10 ..	.....	.....	.....	.....	
8	.....	P?.....	1 45 45	.....	.....	.....	8,300?	More pronounced on E-W than on N-S.
		S?.....	1 55 20	.....	.....	.....	.....	
		eL?...	2 01 00	.....	.....	.....	.....	
		L.....	2 06 ..	24	.....	.....	.....	
		F.....	2 50 ..	.....	.....	.....	.....	
15	.....	eL.....	2 50 00	20	.....	.....	.....	
		F.....	3 10 ..	.....	.....	.....	.....	
17	.....	P.....	11 55 41	.....	.....	.....	3,015	
		S.....	12 00 25	.....	.....	.....	.....	
		eL.....	12 04 40	.....	.....	.....	.....	
		L.....	12 08 00	16	.....	.....	.....	
		F.....	12 13 10	.....	.....	.....	.....	
18	.....	L.....	7 17 ..	.....	.....	.....	.....	
		F.....	7 40 ..	.....	.....	.....	.....	
27	.....	P.....	21 48 28	.....	.....	.....	6,485	
		S.....	21 56 30	.....	.....	.....	.....	
		L.....	22 06 30	.....	.....	.....	.....	
		L.....	22 12 00	16	.....	.....	.....	
		F.....	23 05 00	.....	.....	.....	.....	
31	.....	P.....	23 49 28	.....	.....	.....	2,625	
		S.....	23 53 43	.....	.....	.....	.....	
		L.....	23 58 ..	16	.....	.....	.....	
Feb. 1	.....	F.....	0 40 ..	.....	.....	.....	.....	

CORRIGENDA.

In the REVIEW for October, 1918, page 482, Canada, Toronto, October 19, remarks should be "Possibly Central America."

In the REVIEW for December, 1918, page 586, Table 2, heading "October" should read "December." Page 588, second column should be headed "Hawaii, Honolulu, continued."

SEISMOLOGICAL DISPATCHES.[1]

Havana, Cuba, Feb. 10, 1919.—A slight earthquake shock was felt this morning at Santiago de Cuba, on the southeastern coast of the island. There are no reports of any damage done.—(Assoc. Press.)

Los Angeles, Cal., Feb. 16, 1919.—An earthquake shock, lasting almost a minute, was felt at 8:45 o'clock this morning at virtually every point in Southern California. No damage has been reported from any section.—(Assoc. Press.)

San Francisco, Cal., Feb. 25, 1919.—A slight earthquake was felt here at 2:39 o'clock this afternoon. No damage was reported.—(Assoc. Press.)

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

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Chart I. Hydrographs of Several Principal Rivers, February, 1919.

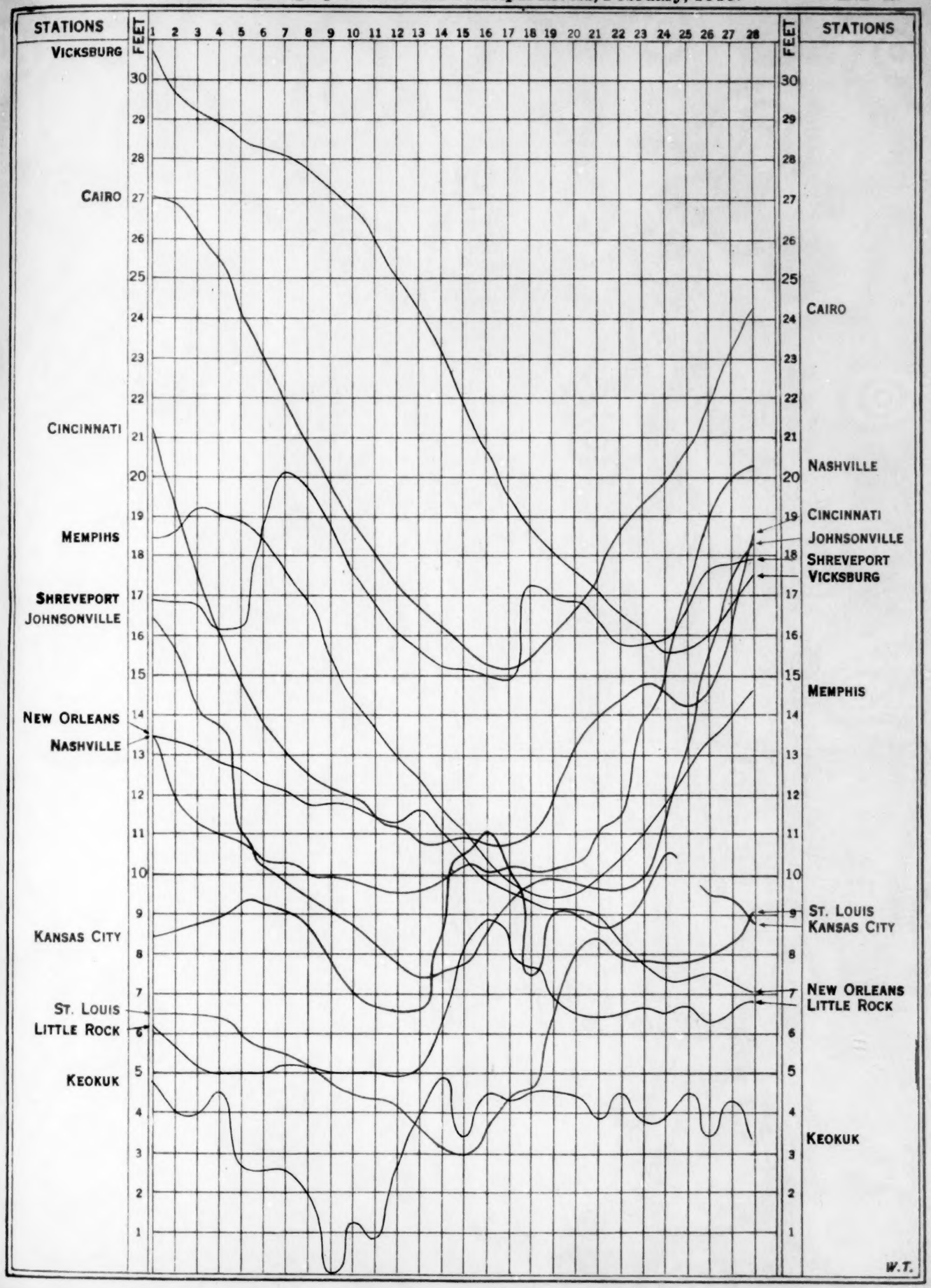

Chart II. Tracks of Centers of High Areas, February, 1919.

(Plotted by Charles A. Donnel.)

Chart III. Tracks of Centers of Low Areas, February, 1919.

(Plotted by Charles A. Donnel.)

Chart III. Tracks of Centers of Low Areas, February, 1919.

(Plotted by Charles A. Donnel.)

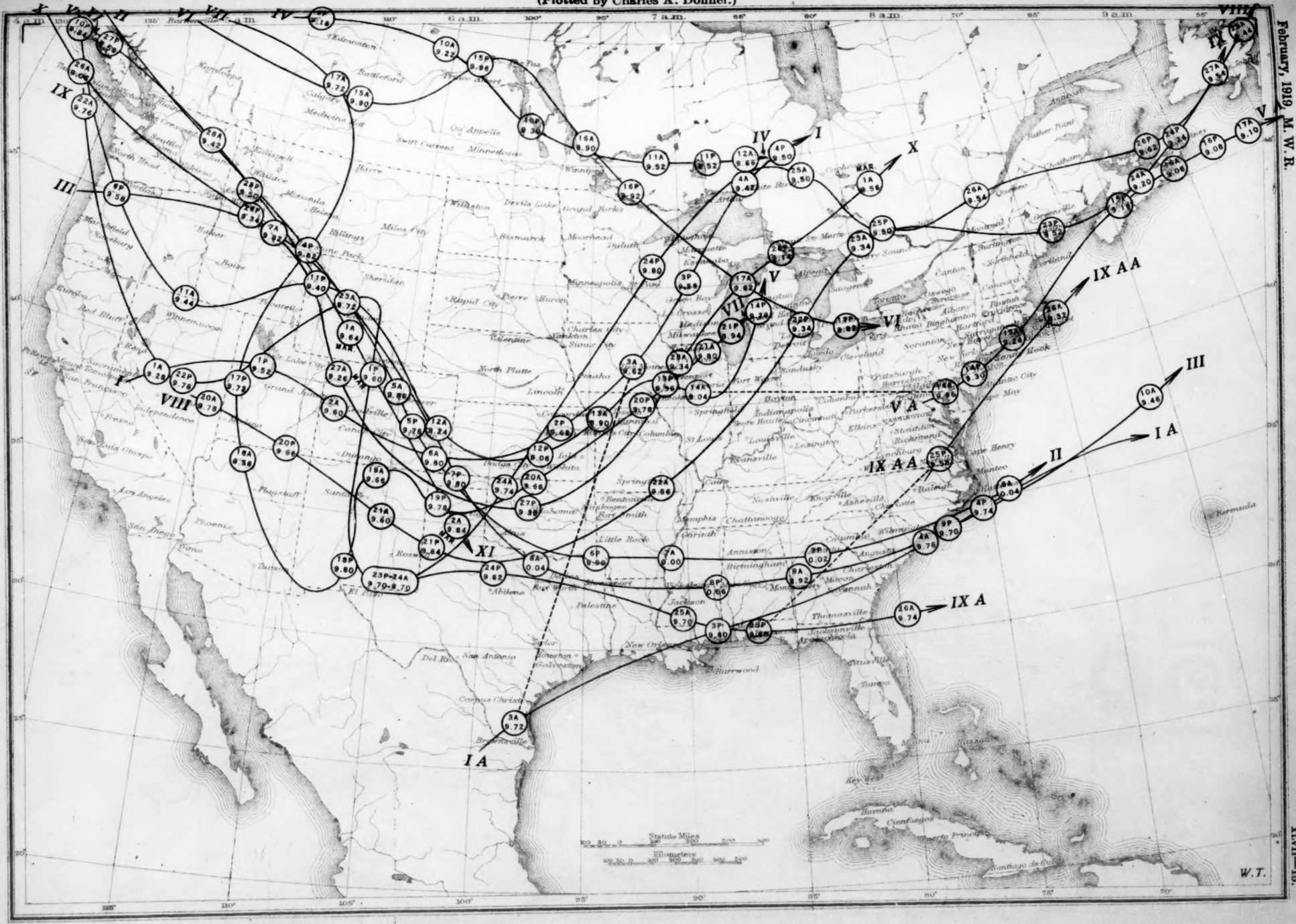

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, February, 1919.

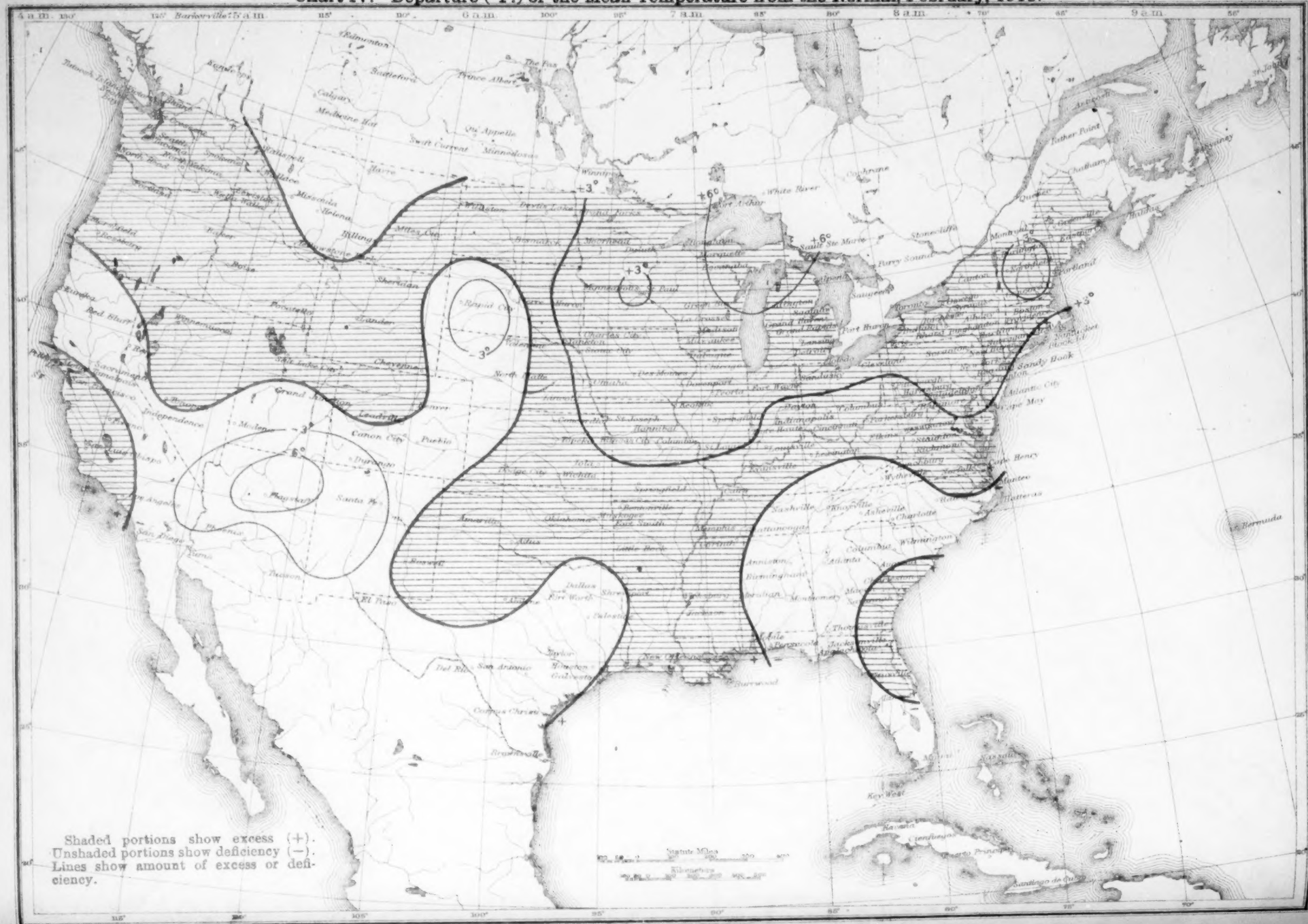

Chart V. Total Precipitation, Inches, February, 1919.

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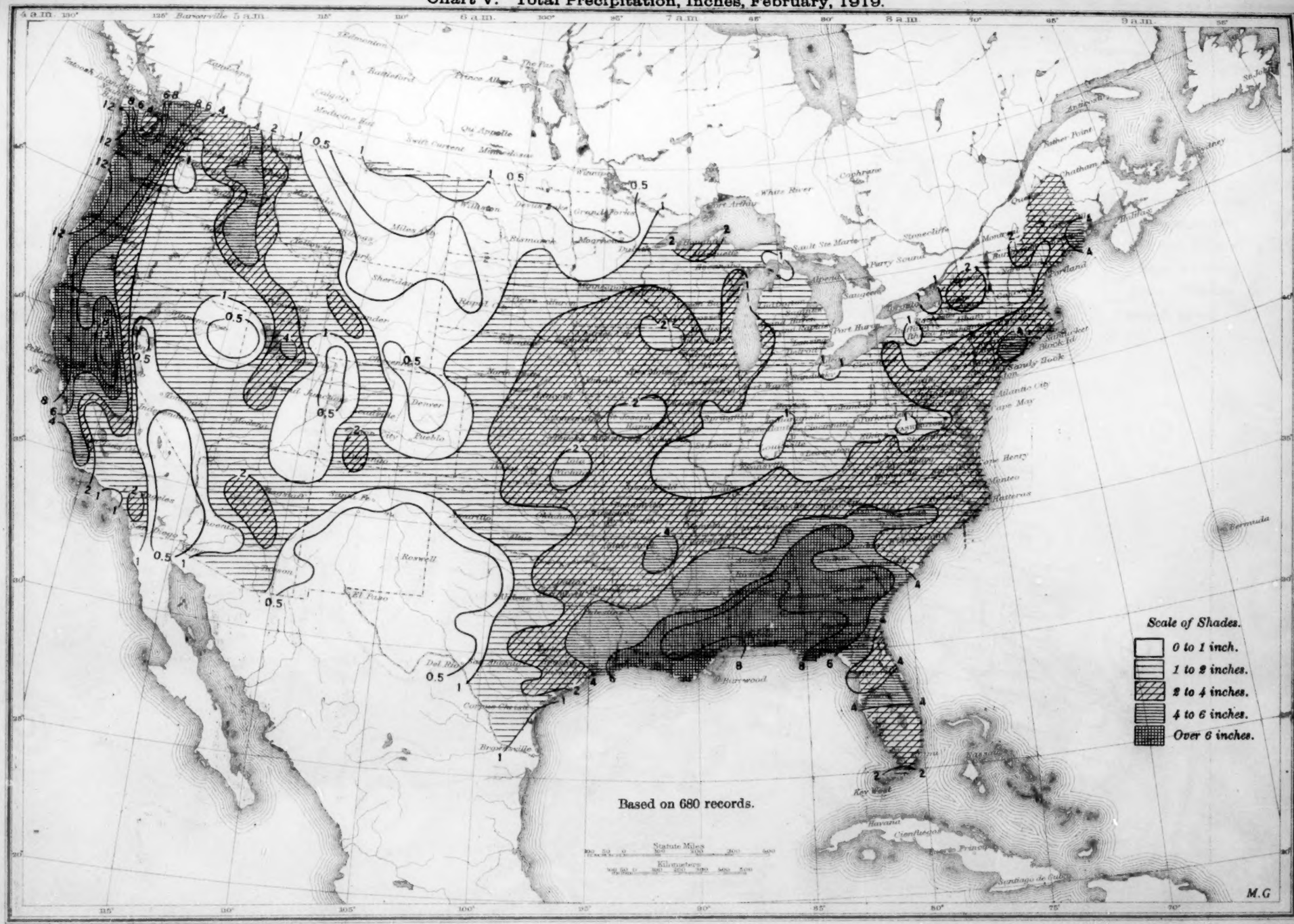

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, February, 1919.

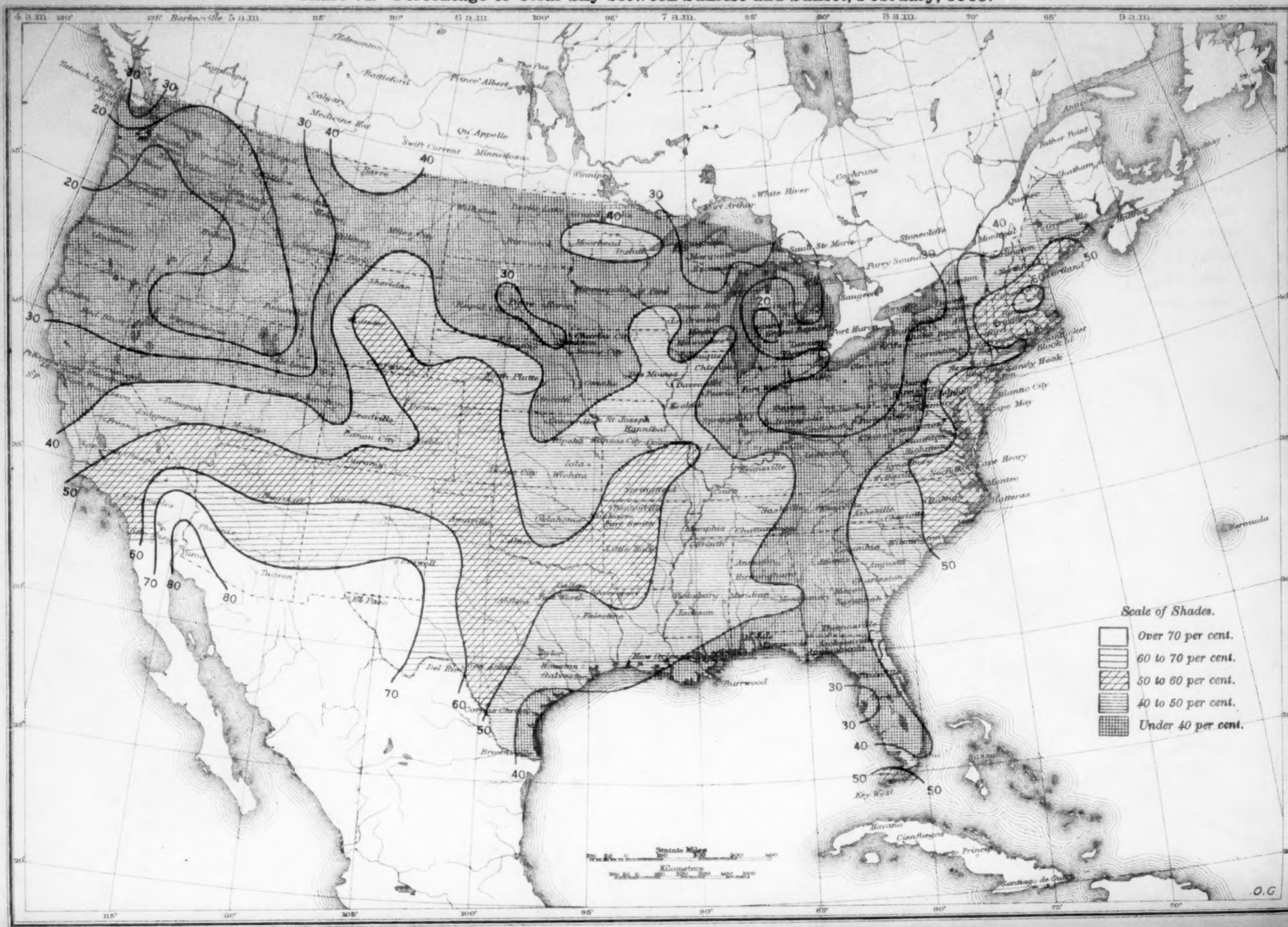

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, February, 1919.

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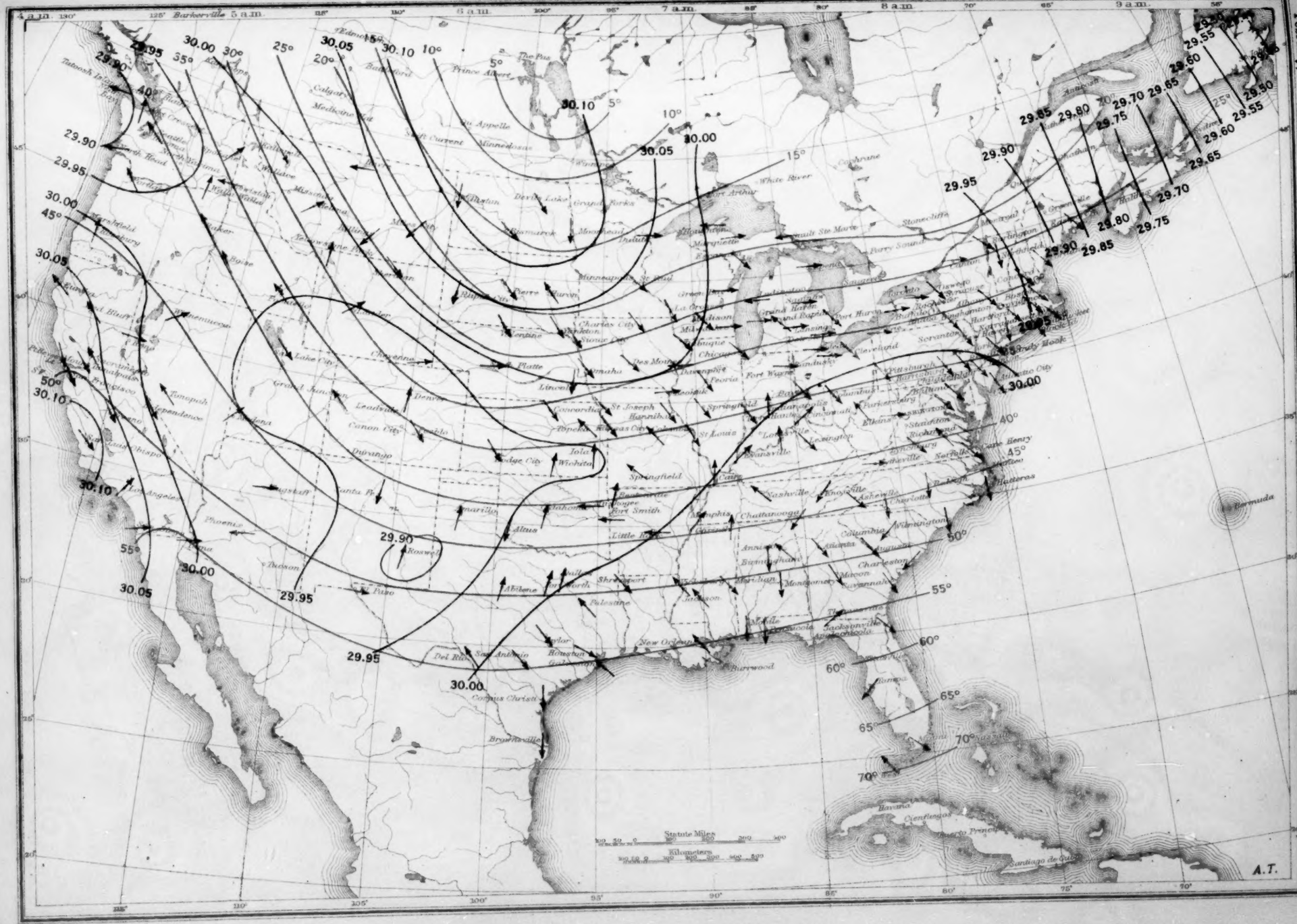

Chart VIII. Total Snowfall, Inches, February, 1919.

Chart IX. Meteorological Data for North Atlantic Ocean, February, 1919.

(Plotted by F. A. Young.)

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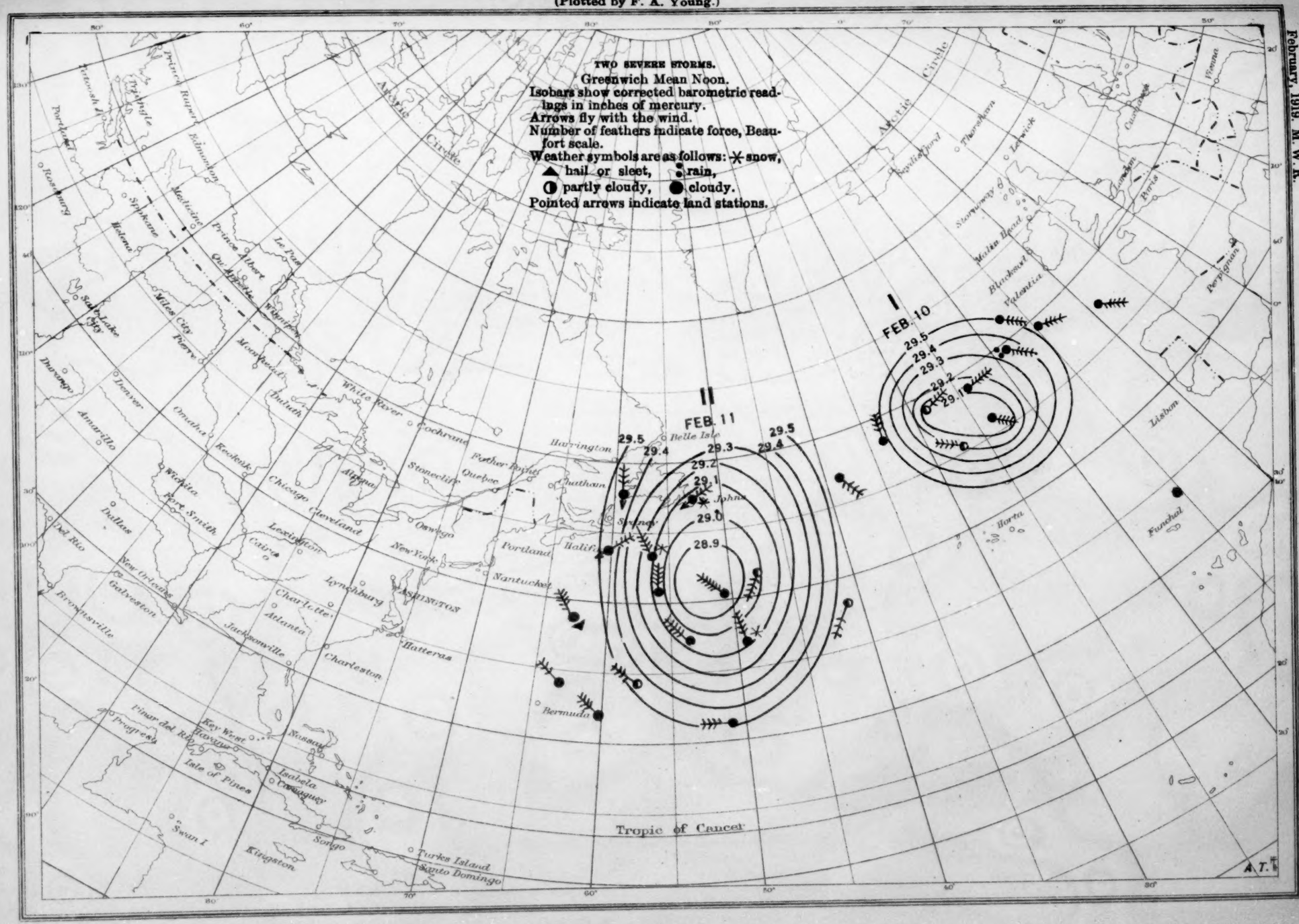
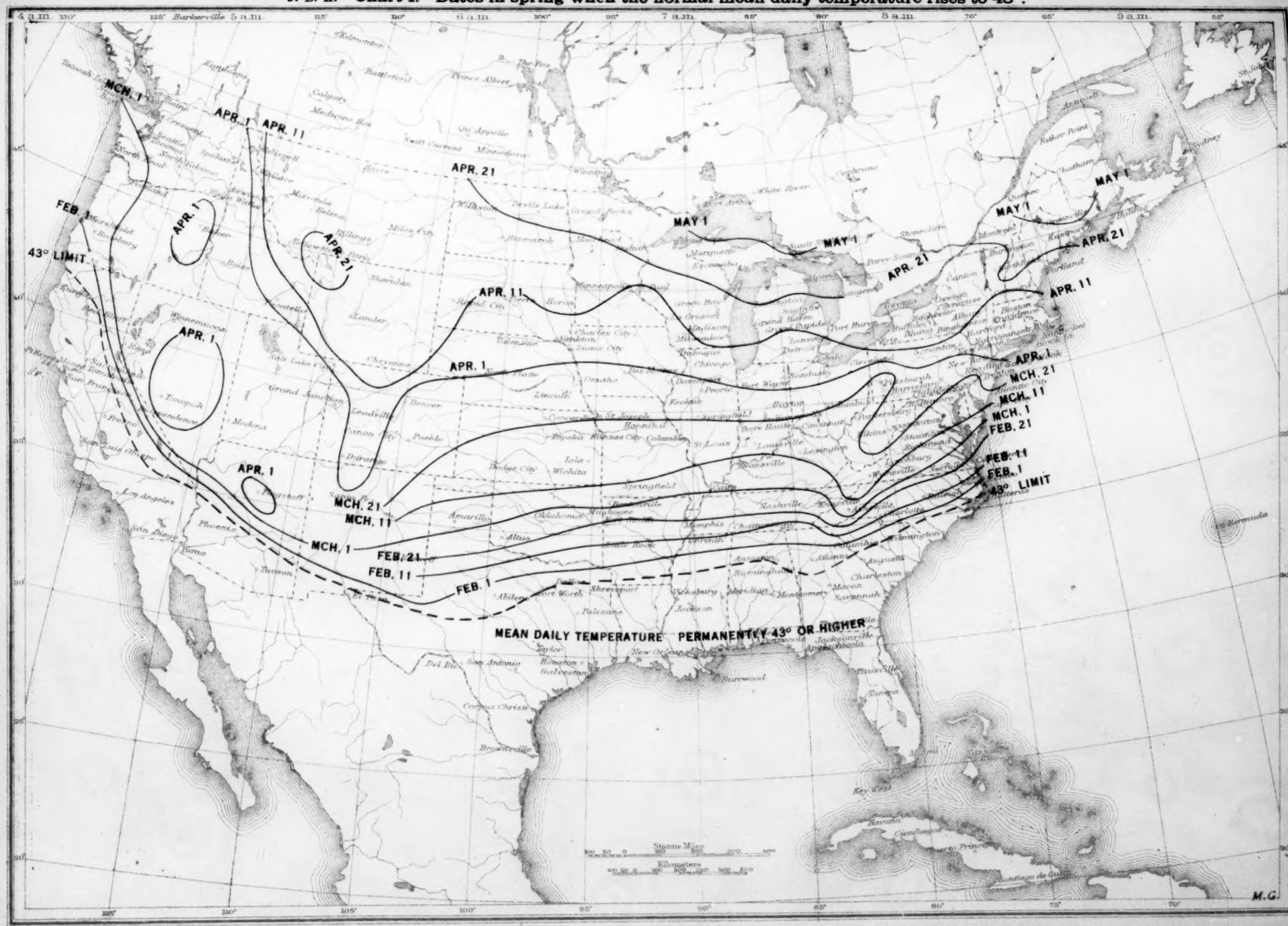
(Plotted by F. A. Young.)

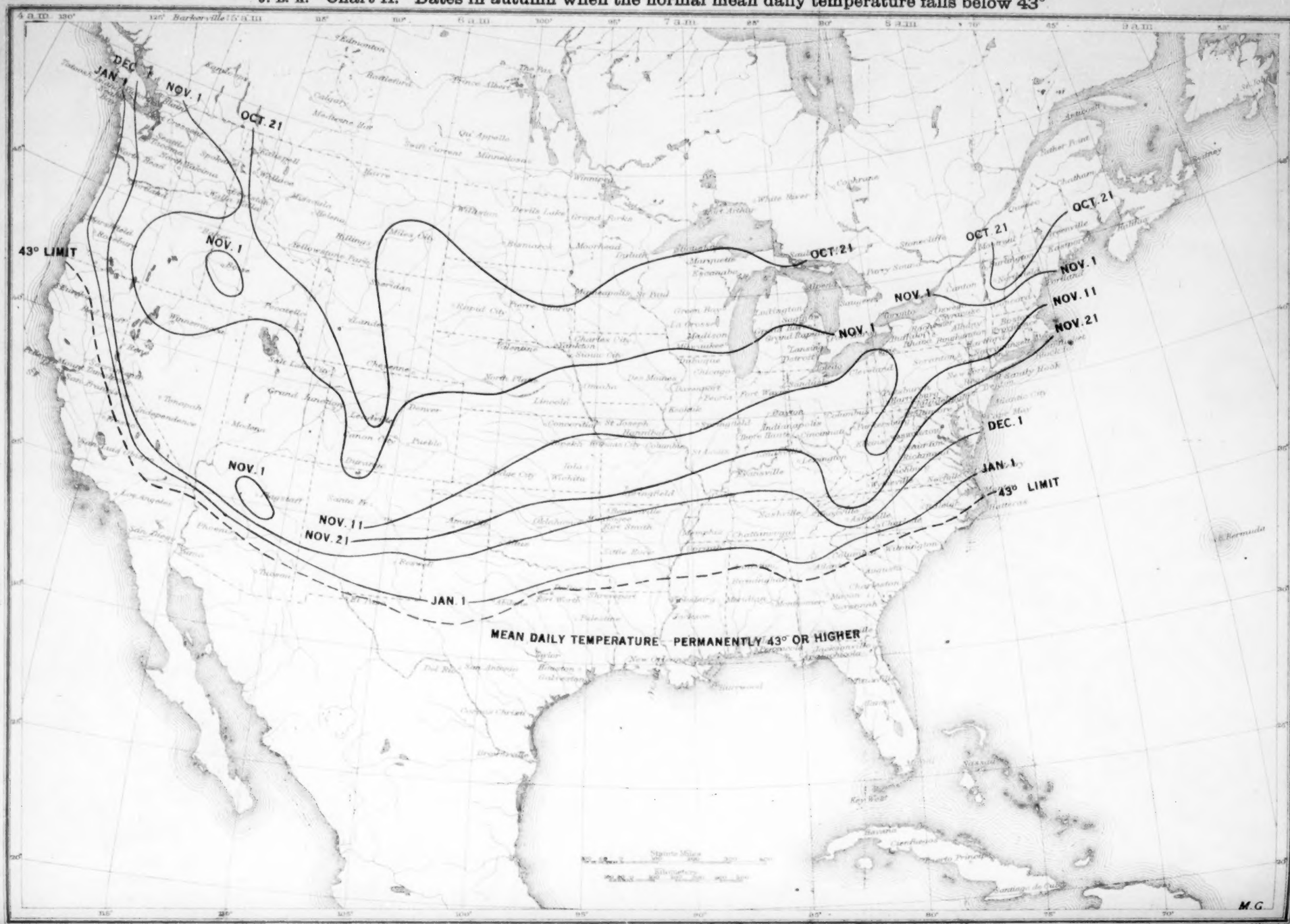


J. B. K. Chart I. Dates in spring when the normal mean daily temperature rises to 43°.

J. B. K. **Chart I. Dates in spring when the normal mean daily temperature rises to 43°.**



J. B. K. **Chart II. Dates in autumn when the normal mean daily temperature falls below 43°**



J. B. K. **Chart III. Average annual number of days with mean temperature 43° or higher.**

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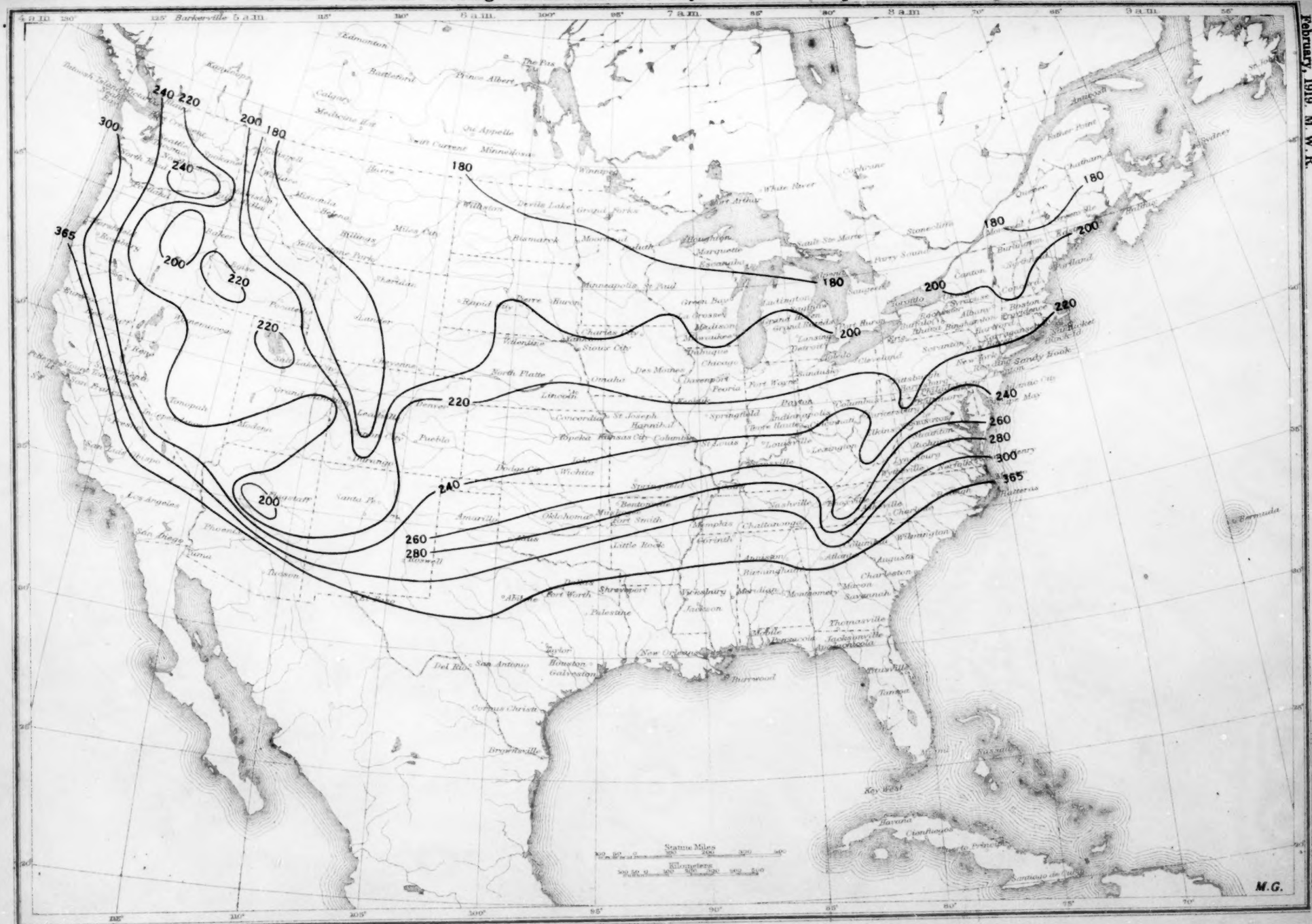


J. B. K. **Chart IV. Normal mean daily temperature on average date of the last killing frost in spring.**

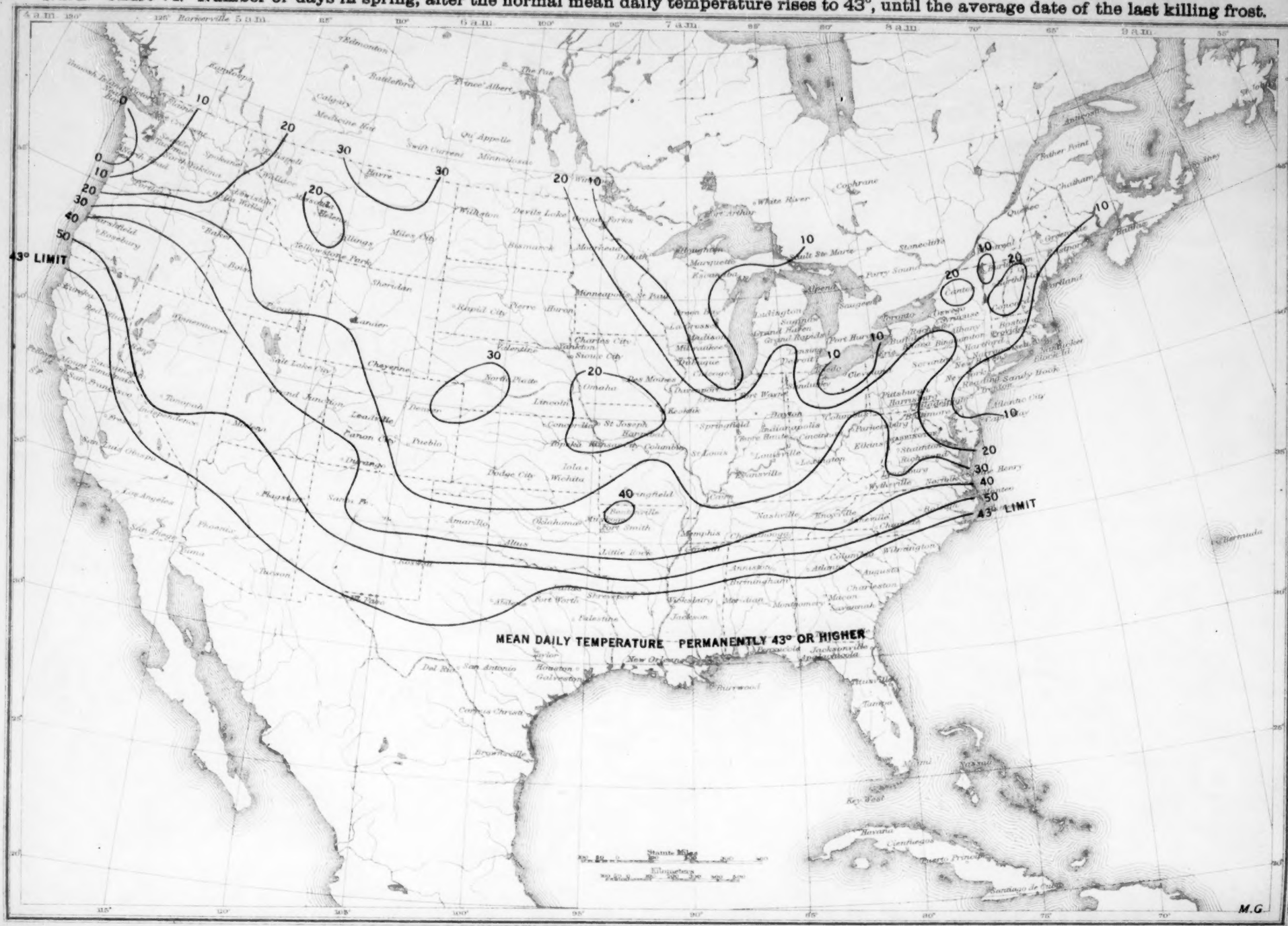
XLVII—25.

February, 1919. M. W. R.

J. B. K. **Chart V. Normal mean daily temperature on the average date of the first killing frost in fall.**

J. B. K. **Chart V. Normal mean daily temperature on the average date of the first killing frost in fall.**

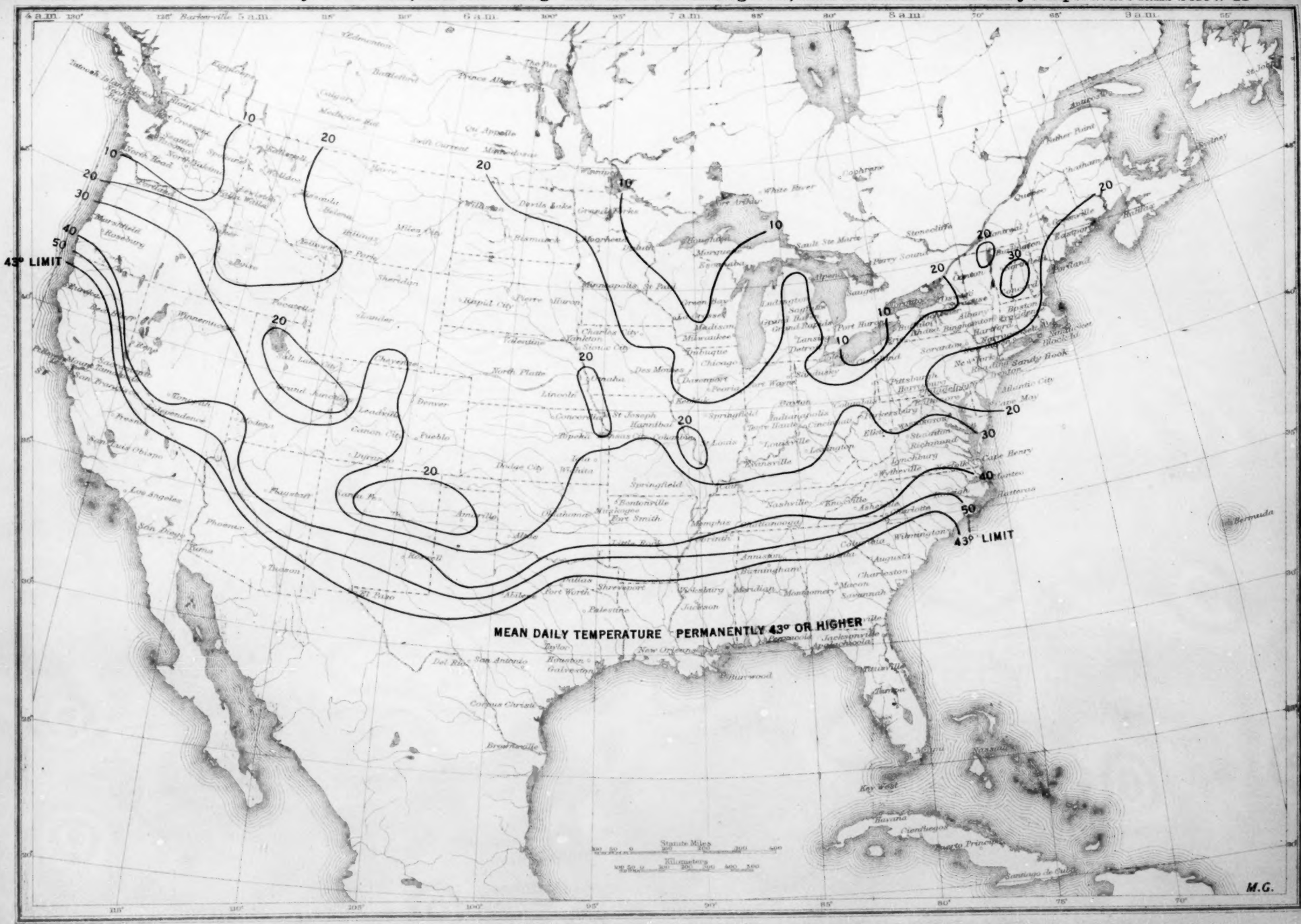
J. B. K **Chart VI. Number of days in spring, after the normal mean daily temperature rises to 43°, until the average date of the last killing frost.**



J. B. K. **Chart VII. Number of days in autumn, after the average date of the first killing frost, until the normal mean daily temperature falls below 43°**

XLVII–27.
February, 1919. M. W. R.

J. B. K. **Chart VII. Number of days in autumn, after the average date of the first killing frost, until the normal mean daily temperature falls below 43°**



J. B. K. **Chart VIII. Number of days the average frostless period is shorter than the average vegetative period.**